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FELLOWSHIP APPLICATION COVER PAGE

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Will animal subjects be used? ☐ Yes ☒ No

APPROVAL DATE: ______ PROTOCOL #: ______ PENDING: ______

Does this application involve any recombinant DNA technology or rese ☐ Yes ☒ No

Plankton dynamics in the Sacramento−San Joaquin Delta: Long-term trends and trophic interactions

2a. Introduction, Questions and Objectives of the Proposed Research

INTRODUCTION

Estuarine ecosystems play an essential role for human life, provide habitat for numerous organisms, and goods and services with high economic values (Lotze *et al.* 2006). The upper San Francisco Estuary, including the Sacramento−San Joaquin Delta and Suisun Bay and Marsh (hereafter collectively referred to as the 'Delta') has become a focal point for understanding complex ecological interactions associated with human activities and climate change. For the last five decades, a near-continuous ecological data set has been amassed and population declines of many pelagic organisms, including primary producers, zooplankton, and fish have been documented, suggesting that the carrying capacity of the Delta's ecosystem to sustain pelagic biota may have been significantly degraded (summarized in Baxter *et al.* 2007). Pelagic organisms decline has motivated research to identify processes underlying the trends and knowledge garnered from these studies has formed the foundation upon which the *CALFED* and other management and restoration efforts for the Delta are being based. The decadal-scale coherence of pelagic organisms declines across different trophic levels (Kimmerer 2004, Cloern 2007) suggests that any change at the base of the food web propagate up to higher trophic levels (Bouley & Kimmerer 2006, Gaines *et al.* 2006). Primary consumers (zooplankton) are a critical trophic link for energy transfer to upper trophic levels and a key food source for threatened and endangered fish species in the Delta. *Yet long-term trends and patterns for primary producers and mechanisms that regulate their abundances remain largely unstudied in this ecosystem despite the fact that the importance of zooplankton forage for fish has been recognized as one potential major component for the observed fish declines (Baxter et al. 2007).*

Historical data analysis of phytoplankton showed high spatial and temporal variability (Jassby *et al.* 2002, Jassby 2008), however the plankton data set has not been fully utilized to understand detailed responses of zooplankton and their interactions with primary producers and environmental variables in the historical context, although a well-documented records of species counts exists. Because the zooplankton community is vital for ecosystem productivity at higher trophic levels, it is timely to take advantage of this historical data resource to understand long-term variability and processes underlying changes in zooplankton to prevent or ameliorate further fish decline and restore ecosystem productivity. *The proposed research aims to understand trends and processes at the base of the Delta's food web by capitalizing on the comprehensive long-term plankton data set. Retrospective food-web analysis will provide important information to better understand the mechanisms by which changes in the primary prey of pelagic fishes contribute to the long-term and more recent drastic decline of fish species of concern.*

The major goal of this proposed study is to identify spatial and temporal plankton variability and biotic interactions by quantitatively analyzing the taxonomically, 33-year plankton data set. The objectives outlined below will help to improve our knowledge about ecological processes underlying the decline of pelagic organisms; in particular it will *(1)* describe spatial and temporal trends in zooplankton, the major food source for native fish species, *(2)* provide a better understanding of the linkages between phytoplankton biomass and zooplankton production, and *(3)* determine how changes in phytoplankton and zooplankton functional groups relate to biotic interactions and environmental changes. We propose that through integrating plankton variability into the management and restoration plan for the Delta, the dynamics of the ecosystem can be viewed from a new perspective that has key implications for understanding the decline in pelagic organisms. As such, this analysis will produce important input to accomplish the *CALFED* mission (CALFED 2000) and for various Delta planning activities to increase pelagic productivity, including the Action Plan for Pelagic Organisms Decline, Delta Vision, or the Delta Regional Ecosystem Restoration Implementation Plan (Baxter *et al.* 2007).

STUDY SITE AND CORE MONITORING DATA SET

Study site: The San Francisco Estuary, including the San Francisco Bay and the Delta is the largest estuary on the US Pacific coast and provides important ecosystem services to the state of California, including supply of drinking water to over 22 million people, irrigation water for one of the world's most productive agricultural centers, and 26,000 ha of open-water habitat for waterfowl and 130 species of fish (Lucas & Cloern 2002, Sobczak *et al.* 2002). The structure and function of the Delta ecosystem changed statically over the last 150 years and all of the Delta's original 1,400 km^2 of tidal marsh have been drained or diked (Nichols *et al.* 1986), and the tributary rivers have been dammed, channelized, and disconnected from their floodplains. River flow is partially controlled by an extensive system of dams, water diversions, and flood channels. The Estuary receives runoff from a 163,000 km^2 watershed. External river inputs are dominated by the Sacramento and San Joaquin Rivers, which provide on average 84 % and 12 % of the Delta's freshwater, respectively (Gaines *et al.* 2006). Flow rates exhibit considerable seasonal and annual variation and reflect wet winters and dry summers linked to large-scale climate oscillations (Kimmerer 2004). As a result water residence time varies greatly across years and stations. Much of the variability of pelagic organisms in the Delta is associated with hydrology, for example high hydrological variability strongly affects phytoplankton biomass through fluctuations in flushing and growth rates through fluctuations in transparency (Jassby 2008), and it can be expected that flow rates will also affect zooplankton community dynamics.

External river inputs account for 60 % of annual organic matter supply to the Delta; in contrast primary producers within the system account for 15 %. Autochtonous primary production is dominated by phytoplankton, while production by macrophytes and benthic algae is relatively small (Cloern 2001). The habitat types in the Delta are open systems where pelagic food-supply is provided both by import from connecting habitats as well as from internal production (Lucas & Cloern 2002, Cloern 2007).

This study will focus on the Delta, a heterogeneous environment of tidal freshwater habitats, including channels, sloughs, shallow lakes, and estuarine embayments, connecting a 1.6 x 10^7 ha watershed to the San Francisco Bay (Jassby & Cloern 2000). Water salinity varies widely within the system, ranging from fresh in the Delta to coastal salinities near the mouth of the Bay to sometimes hypersaline conditions during droughts in southern parts of the Bay. The boundary between the limnetic (salinity of 0-0.5) and oligohaline (salinity of 0.5-5) zones during median flow conditions is at Chipps Island, near the confluence of the Sacramento and San Joaquin Rivers (for map see Kimmerer 2004).

In addition to human-induced disturbances the ecosystem has been changed due to accelerating invasion of non-native species (Cohen & Carlton 1998). As of 2002, a total of 234 exotic species established in the ecosystem, including plants, protists, invertebrates, and vertebrates. Some of the most widespread invaders that vastly changed ecosystem processes include the suspension-feeding clam *Corbula amurensis* (Alpine & Cloern 1992, Jassby *et al.* 2002), which suppressed phytoplankton production. The zooplankton community also changed significantly due to the introduction of various copepod species including *Pseudodiaptomus forbesi, Eurytemora affinis,* and *Limnoithona tetraspine*, which all have established large populations (Orsi & Ohtsuka 1999, Bouley & Kimmerer 2006). These invaders feed at various trophic levels and largely increase the competition for food resources with native species. For instance the non-native clams compete with zooplankton for algae (Bennett *et al.* 2002) and exotic fishes compete with native fishes for invertebrate prey (Bennett *et al.* 2002).

The long-term declining trend of the pelagic fish species in the estuary (Bennett *et al.* 2002, Baxter *et al.* 2007), including Delta smelt (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), striped bass (*Morone saxatlis*), and Chinook salmon (*Oncorhynchus tshawytscha*) is to a large part associated with variation of outflow in the estuary. However, abundances of these species declined sharply around 2000 despite relatively moderate hydrology (Baxter *et al.* 2007). Because these fish species show vast differences in their individual life histories (Moyle 2002), it is expected that a combination of factors contribute to the recent collapse and that the environmental conditions such as habitat quality and/or zooplankton forage have fundamentally changed in the Delta.

The water quality data show that in addition to reduced pelagic productivity, the Delta as a whole is becoming saltier, warmer, and more transparent (Kimmerer 2004, Dettinger 2005). These changes are associated with a shift in the seasonal pattern of freshwater inflow to the Delta, and an increase in freshwater export over the last decades (Cayan *et al.* 2001, Dettinger *et al.* 2004). Due to warming trends of the regional climate, the timing of runoff peaks shift towards earlier in the season. The long-term trend of increasing water clarity is largely attributed to reduced sediment input presumably due to dam construction (Kimmerer 2004, Jassby 2008).

<u>Core data for the proposed research:</u> Among the most detailed of the long-term data sets available in ecology is that collected in the Bay-Delta from before 1975 through the present. The comprehensive monitoring activities are managed by the Interagency Ecological Program (IEP; www.iep.water.ca.gov), a consortium of state and federal agencies. Major physical, chemical, and biological parameters have been monitored regularly at approximately monthly intervals since 1975 (Kimmerer 2004, Hennessy & Hieb 2007). This discrete sampling program has used consistent methods since their inception, although the number and distributions of stations have hanged in some cases. In addition abiotic variables (e.g., temperature, salinity, turbidity, flow rates) are measured at high frequency (around every hour) at few stations. The California Department of Fish and Game (DFG) are responsible for collecting zooplankton and the water quality data, while the California Department of Water Resources (DWR) is responsible for phytoplankton and additional water quality data collections. The USGS program for the San Francisco Bay also extends into the Delta at Rio Vista. This historical data set is exceptional in its temporal and spatial coverage, consistency over time and multiplicity of measured variables.

PROPOSED RESEARCH

High temporal variability in estuarine ecosystems poses a challenge for observing and understanding causes and consequences for ecosystem dynamics. Long-term ecological research is of importance to extract seasonal, interannual and inter-decadal variability from random noise and to emphasize underlying processes. Analysis of the Delta's historical data set were especially instructive demonstration of the utility of this type of research (e.g., Jassby & Cloern 2000, Bennett *et al.* 2002, Jassby *et al.* 2002, Kimmerer *et al.* 2005, Cloern *et al.* 2007) and results from those done clearly indicate their value. Outstanding examples of the value of such studies include the decadal-scale investigation of primary producers in the Delta and San Francisco Bay (Jassby *et al.* 2002, Cloern *et al.* 2007, Jassby 2008). These studies demonstrate that impacts operating at different time scale affect ecosystem dynamics, indicating the importance of long-term data analysis. The focus on decadal-scale analysis in the Delta research has mainly concentrated on identifying patterns in abiotic factors, including change in salinity, nutrient concentration, suspended material as well as on primary producers and pelagic fish organisms (see overview in Baxter *et al.* 2007). Except for a few studies on the identification of major zooplankton trends and change in community composition (Kimmerer *et al.* 1994, Orsi & Ohtsuka 1999, Bouley & Kimmerer 2006, Cloern 2007), detailed zooplankton patterns and quantitative food-web linkages remain largely unstudied. With the availability of detailed long-term data sets of major components of the pelagic food web, environmental variables, and sophisticated time series analysis we have a set of established tools to evaluate trophic linkages in the Delta's pelagic food web in a comprehensive fashion. The dynamics of pelagic estuarine communities and biotic interactions will be better understood by applying such a food-web modeling approach and will equip us better with management tools to restore ecosystem function and structure.

The proposed study will fill the gap of knowledge of spatial and temporal patterns in zooplankton variability and interactions within the planktonic community and the environment. In year 1 spatiotemporal variation and trends of zooplankton will be identified and year 2 will concentrate on interactions between phytoplankton, primary consumers and environmental variables.

***Objective 1*: Identification of long-term spatial and temporal patters in zooplankton**

Background – Zooplankton transfer energy from primary (phytoplankton) and bacterial production to higher trophic levels such as fish and are thus an important link in the aquatic food web. All Delta fish species that have declined in abundance have pelagic-feeding larval stages (e.g., Chinook salmon) and some species feed on zooplankton through their entire life history; for example copepods are the primary dietary components for delta smelt (Nobriga 1998). This indicates that zooplankton production will be important for fisheries restoration.

The zooplankton community in the Delta is dominated by rotifers, cladocerans, copepods, and mysids (Table 1). Previous analysis indicated that cladocerans are abundant in spring, whereas copepods do not exhibit clear seasonal patterns (Obrebski *et al.* 1992). There is however high spatial and seasonal variability in the abundance of copepod species among the estuary habitats. Substantial changes in abundance and species composition due to species invasion from East Asia have occurred over the last three decades (Orsi & Ohtsuka 1999), resulting in apparent changes in trophic structure. The sampling period before 1987 was characterized by declines in many species in the Delta (Obrebski *et al.* 1992, Kimmerer *et al.* 1994) including rotifers, cladocerans, and copepod species (Kimmerer 2004, Cloern 2007). Potential reasons for the decline are attributed to reduced phytoplankton biomass, increased export pumping, reduced organic input, or effects of toxic compounds. Over the same time period introduced cyclopoid copepod species, including *Oithona davisae* and *Limnoithona sinensis* increased significantly.

Since the late 1980s the zooplankton fauna underwent substantial changes mainly associated with species introductions. Abundances of *Eurytemora affinis* and *Acartia* spp. declined sharply due to the effects of clam introduction (Bennett *et al.* 2002) and subsequent decline in phytoplankton availability (Jassby *et al.* 2002). The copepod *Pseudodiaptomus forbesi* was first recorded in this estuary in 1988 and is now the dominant calanoid copepod of the low-salinity zone in terms of biomass. The calanoid copepods *P. forbesi* and *E. affinis* are an important food source for key fish species and previous analysis showed that both species have significantly declined at almost all long-term monitoring stations over the last decades (Fig. 1). The small cyclopoid copepod *Limnoithona tetraspina* (length 0.5 mm) has become the numerically dominant copepod since its introduction in 1993 in the low-salinity regions (Bouley & Kimmerer 2006). It feeds primarily upon ciliates and microflagellates, but unlike *P. forbesi*, it is relatively impervious to predation by clams or fish. Low selectivity of fish for this cyclopoid copepod species suggests that it may not be an important food resource for visually-selective fish (Bouley & Kimmerer 2006) and energetically a dead end for the food web. This suggests that zooplankton species composition is a useful indicator of the food quality for fish. Thus, in addition to zooplankton declines, displacement of nutritious by low-nutritious zooplankton forage is likely another underlying factor for the observed fish declines (Baxter *et al.* 2007).

These general trends and patterns of the zooplankton community illustrate that the zooplankton community changed substantially over the last decades. In addition to long-term interannual fluctuations, estuarine environments exhibit strong seasonal variability (Winkler *et al.* 2003, Islam *et al.* 2006), which likely affect seasonal zooplankton abundances. As a result, food availability for native fish species may vary greatly on a seasonal basis resulting in potential mismatch between fish larvae development and zooplankton forage. Life histories of fish species of concern have been described in the Delta (Moyle 2002, Baxter *et al.* 2007) and understanding long-term seasonal zooplankton variability will be crucial to identify potential disruption between the zooplankton-fish trophic link.

To understand spatial and temporal long-term trajectories of zooplankton species and functional groups the following questions will be addressed:

(1a) What are the long-term trends of Delta's zooplankton community and can distinct sub-regions be identified that show similar patterns?

Rationale. The Delta is a heterogeneous environment that experiences various degrees of environmental change at different time scales (Kimmerer 2004) and thus high temporal and spatial variability in zooplankton dynamics can be expected. Preliminary trend analysis of zooplankton species showed that the majority of zooplankton species declined significantly at all sampling stations; some species maintained their abundances in specific regions over the record period, while few species showed an increasing trend (see preliminary analysis in Fig. 2). This part of the project will identify long-term zooplankton temporal patterns at Delta-wide scale. Due to large environmental heterogeneity large differences can be expected within stations, thus sub-regions that have experienced similar zooplankton trajectories will be identified, which is expected to result in a clearer picture.

Focal zooplankton response variables will be of two general types: single taxon abundance, and aggregate community properties, including total zooplankton biomass and functional groups. Functional groups will be categorized according to (*a*) feeding ecology (i.e., herbivores, omnivores, predators) and (*b*) nutritional value as forage for fish (i.e., low nutritious vs. high nutritious). The latter category will be a useful indicator on how food quality for fish species changed, which largely depends on zooplankton species composition (Bouley & Kimmerer 2006). Zooplankton nutritious value for fish will be based on fish preference outcome from experiments and energetic forage cost for fish (see overview of planned experiments in Baxter *et al.* 2007), as well as on measured essential fatty acid composition. Herbivorous zooplankton species (e.g., cladocerans, calanoida) are expected to be of higher food quality because they graze on phytoplankton and are preferred prey item for fish , whereas predatory copepods (e.g., *Limnoithona spp.)* are expected to be a low nutritious food source. Understanding differences in patterns of influential zooplankton species and zooplankton forage quality for fish will be a first critical step to identify underlying mechanisms useful for management and restoration efforts.

(1b) What are the long-term seasonal patterns in zooplankton species and functional groups?

Rationale. The Delta ecosystem is highly variable at a seasonal scale, driven by environmental variables of freshwater flow rates, solar radiation, and temperature (Kimmerer 2004). Population dynamics of zooplankton in the system are strongly tight to the seasonality of temperature and resource availability and variation of these extrinsic factors can strongly modify the temporal population fluctuations in these organisms. Understanding long-term seasonal variability of zooplankton forage quantity and/or quality will be crucial for fish production, which exhibit different life histories and thus the timing of larval stages vary among species (summarized in Baxter *et al.* 2007). To better understand long-term seasonal variability in zooplankton, trends will be investigated at a seasonal basis for influential species and zooplankton aggregates (see above). Zooplankton functional groups will indicate to what extent species displacement affected the seasonal variability of food quality for fish.

***Objective 2:* Identifying long-term interactions between primary producers and zooplankton**

Background – Primary production is the key energy source that sustains higher trophic levels and particularly in the Delta phytoplankton production fuels the pelagic food web (Jassby *et al.* 2002, Sobczak *et al.* 2002, Sobczak *et al.* 2005). Parallel decline in primary production, stocks of zooplankton and fish suggests that changes at the base of the food web and higher trophic levels are linked. Primary production rates in the Delta are inherently low because of light limitation (Jassby *et al.* 2002, Lopez *et al.* 2006) and growth and reproduction of crustacean zooplankton are limited by low phytoplankton biomass (Muller-Solger *et al.* 2002, Choi *et al.* 2005). The extent to which change in phytoplankton affect zooplankton production have however not been investigated in the Delta. Understanding this trophic linkages at large time scales and among stations will reveal whether bottom-up processes from primary producers to primary consumers are consistent or whether other mechanism such as species interactions or abiotic factors regulate zooplankton population dynamics.

Trends of primary producers measured as total phytoplankton biomass and gross primary productivity rates revealed spatial differences and an overall strong long-term declining trend (Jassby *et al.* 2002); for example production declined more then 40 % between 1975 and 1995. Current levels of average chlorophyll concentrations below 10 µg L^{-1} are below the earliest-recorded values (Jassby 2008). Feeding threshold values for most zooplankton organisms are within this range (Muller-Solger *et al.* 2002), thus declining trends may have critically affected zooplankton growth rates in this low-productivity system. A more recent analysis however indicated that phytoplankton biomass and production increased since the mid 1990s, particularly in the upper Delta region (but not in Suisun Bay), which is linked to reduced freshwater flow and increasing water clarity (Jassby 2008). Despite the recent recovery of primary production, primary and secondary pelagic consumers declined further and particularly fish species of concern declined drastically over the last recent years (Baxter *et al.* 2007). This suggests that while reduced primary production was likely the cause for the earlier decline, recent decline in zooplankton abundances can not be attributed to change in primary production.

Trophic ecology studies indicated that the diet composition varies among zooplankton species (Gifford *et al.* 2007). For example, the copepod *Acartia spp.* prey mainly on algal cells (diatoms and flagellates) and heterotrophic prey (ciliates and flagellates) in the size range >10 µm (Rollwagen Bollens & Penry 2003). Feeding experiments showed that the two copepod species, *E. affinis* and *C. ovata,* capitalize different plankton species (Mueller-Solger *et al.* 2006). *E. affinis* grazes indiscriminately on available algal and protozoan prey organisms, while *P. forbesi* more actively selects algal cells, particularly centric diatoms, and exerts a greater grazing pressure on its chosen prey. Experiments with the cyclopoid copepods like *L. tetraspina* showed that this abundant small species preys upon mixotrophic and hetertrophic ciliates, but rarely on diatoms (Bouley & Kimmerer 2006, Gifford *et al.* 2007). Because the importance of phytoplankton as a food source for zooplankton varies across species, temporal and spatial zooplankton changes may be independent of any change in primary producers and may explain why zooplankton did not respond to the recent recovery in phytoplankton.

This part of the proposed research aims to analyze long-term interactions of the phytoplankton-zooplankton trophic link, which will provide important information to what extent change in primary production and environmental variables affect primary consumers. This will be achieved by focusing on following questions:

(2a) **How does phytoplankton and environmental variability affect zooplankton production at Delta-wide scale and appropriate sub-regions?**

Rationale. The plankton community in the Delta consists of different functional zooplankton species, including herbivores, omnivores, and predators, and thus it is expected that interactions between primary producers and primary consumers will differ among species. Besides food availability, zooplankton is also affected by abiotic factors such as freshwater flow rates and temperature. This part of the project will focus on understanding underlying processes for zooplankton variability. The response of zooplankton taxa and functional groups (see objective 1) to phytoplankton biomass, measured as chlorophyll concentration, and environmental variability will be analyzed across stations and for specific sub-regions identified for zooplankton in Objective 1 over the long-term and recent sampling record. Identification of regions with strong phytoplankton and zooplankton coherence will be indicative that bottom-up processes regulate primary consumer production, whereas weak coherence likely indicate that other factors limit zooplankton production. It is likely that zooplankton species displacement towards different functional groups that prey upon microzooplankton can be an underlying factor for the discrepancy. The outcome of this part will be informative to what extent change in primary producers and environmental variation affect zooplankton variability, and thus the energy transfer to upper trophic levels. Understanding differences and patterns across sub-regions or stations will be useful for restoration effort such as some regions may represent desirable restoration outcome with high trophic efficiency, while others can serve as baseline stations for restoration scenarios.

***(2b)* Are seasonal patterns between primary producers and zooplankton consistent throughout the sampling record?**

Rationale. Copepods, the dominant zooplankton group and important food source for fish species of concerns in the Delta are relatively long-lived zooplankton species and duration of development varies between few weeks to one year. Successful life-cycle completion requires both synchrony with food availability and synchrony between development time and the time window of the available growing season (Cushing 1990, Edwards & Richardson 2004). Because estuarine habitats exhibit strong seasonal dynamics, it can be expected that the declining trend in zooplankton is linked to seasonal shifts in population dynamics resulting in a temporal disruption with their food resource. This part of the project will identify whether seasonal population dynamics of primary producers and influential zooplankton species and aggregates (see objective 1) were consistent over the sampling period or whether shifts in seasonality occurred. Seasonal shifts in zooplankton population dynamics may critical for fish development and result in a mismatch between food availability for fish species relative to fish growth performance.

***Objective 3:* Identification of biotic interactions in the plankton community**

Background – Experimental food-web studies indicate that phytoplankton is a major food source for zooplankton. While phytoplankton production recovered during the last decade, zooplankton however did not respond to the recent increasing primary production trend (Cloern 2007, Jassby 2008). This discrepancy supports the notion that primary producers are a potential underlying cause for zooplankton decline until early 1990, but not afterwards. It is expected that the further decline of zooplankton populations is in part linked to change in algal food quality and/or palatability (Mueller-Solger *et al.* 2006), which depends on algal taxonomic composition (Brett & Muller-Navarra 1997) and cell morphology (Reynolds 2006). There is some evidence that phytoplankton community composition changed over the last decades in the Delta towards a shift of lower algal food-quality (Lehman 1996, Choi *et al.* 2005, Lehman *et al.* 2008). The proportion of diatoms decreased particularly during 1975 and 1989, caused by a decreasing trend in diatoms and an increasing trend in chlorophytes, cyanobacteria, and phytoflagellate abundances (Lehman 1996, Choi *et al.* 2005, Lehman *et al.* 2008). While there has been no discernable change in diatoms and phytoflagellates after 1990, cyanobacteria blooms of *Anacystis* and/or *Microcystis* have become an increasingly common phenomenon in the Delta in recent years (Lehman *et al.* 2008). Diatoms and cryptophytes are of high food quality for zooplankton because of their enrichment in essential fatty acids, whereas cyanobacteria have relatively low nutritional value (Brett & Muller-Navarra 1997). This indicates that the algal taxonomic composition is informative for the nutritional value for primary consumers, which is supported by experimental work indicating that algal species composition regulates zooplankton growth performance (Muller-Solger *et al.* 2002) and copepod production in the Delta (Mueller-Solger *et al.* 2006).

In addition to zooplankton displacement (see objective 2), change in food quality may be another reason why recent recovery of phytoplankton biomass (measured as chlorophyll concentration) did not translate into increasing zooplankton production. To fully understand the underlying processes that limit zooplankton production, algal food quality should be considered in trophic interactions. Such an approach however requires detailed species counts. Whereas the historical record for zooplankton is sufficient for such an approach, previous examination of the phytoplankton data set revealed limitation of its usage at the species level because the precision of the species values is overall low and small-sized cells have not been counted (Hymanson & Mueller-Solger 2001-2002). Analyses at the species level are therefore not recommended and phytoplankton biovolume can not be estimated based on algal cell counts. Nevertheless, the data are reliable at the class level and focusing on major phytoplankton groups will provide useful information for overall changes in food-quality for primary consumers.

Because all populations are embedded in a community, identifying dominant biotic interactions in the pelagic food web of the Delta and how they are affected by environmental variability will be important to understand underlying processes for plankton variability. At present, plankton biotic relationships are based on laboratory experimentation, observations, inferences from literature, and quantitative analyses between benthic grazers and phytoplankton biomass (Jassby *et al.* 2002, Kimmerer 2004). A cohesive analysis of the long-term dataset that includes different phytoplankton and zooplankton functional groups is still lacking in the Delta. While a detailed food-web modeling approach is too extensive within the 2-year funding period, basic interactions between phytoplankton functional groups and zooplankton trophic guilds, and environmental variables will be identified. If the available data are promising for food-web modeling, this will provide useful information for a more detailed analysis, which will be pursued if funding is continued. Within the 2-year funding period the following question will be addressed:

***(3a)* How do changes in plankton community composition relate to biotic interactions and environmental variation?**

Rationale. This part of the project will apply a quantitative multivariate analysis approach to investigate interactions between phytoplankton functional groups based on their nutritional value and zooplankton aggregates. In addition, changes in exogenous drivers, such as salinity, freshwater flow, and water temperature will be considered. Given that the quality of the phytoplankton data is sufficient for this analysis, the results will identify major species interactions and pathways through which abiotic variables may act on communities. Analyzing trophic food-web interactions at community-wide scale will be an important step in understanding the functioning of the pelagic communities and how they respond to environmental change.

2b. Approach and Plan of Work

Data source: Zooplankton, phytoplankton, chlorophyll and environmental data from 1975 to present will be provided by the California Departments of Water Resources and Fish and Game. Data for flow are available at http://www.iep.ca.gov/dayflow/index.html. The analysis will focus on long-term zooplankton monitoring stations in the Delta (around 14 stations, for map and station location see Mueller-Solger *et al.* 2006).

Approach for historical data analysis: A very large number of techniques are available for analyzing and understanding processes or mechanisms from long-term time series. Specific applications evolve from scientific understanding, the nature of the data as revealed through graphical exploration, the tools available to the analyst and trial-and-error. It is not possible to determine the exact course of an analysis beforehand. Specific previous time series analyses used in this estuary have been proven to be very successful. To address the proposed objectives some of these time series procedures and techniques applied in other aquatic systems will be used, while alternatives will be also explored in practice but will not be listed here.

Trend analysis – Monthly zooplankton will be used to identify long-term trends of the Delta's zooplankton species (Table 1). The temporal dynamics of the zooplankton will be characterized using single taxon abundances of influential community members and aggregate community properties (functional groups) based on biomass estimates to reflect the true contribution of individual species to total composition. The division into aggregate properties will be accomplished based on taxonomy (cladocerans, copepods, rotifers), knowledge of zooplankton ecology (herbivores, omnivores, predators), and food-quality for fish, based on nutritional value (for analysis see below). Zooplankton densities counts will be converted to biomass using established length-weight regressions from the Delta (available from A. Mueller-Solger and Bouley & Kimmerer 2006), or if not identified regressions will be measured (see below). Rotifer biomass will be estimated from literature sources (Hutchinson 1982, Walz 1995). If life stages are differentiated (see Table 1), biomass will be estimated for each stage to calculate total biomass.

For each zooplankton species and station, abundance/biomass will be binned by month using the mean to form a collection of monthly time series or by salinity intervals, which may reduce noise due to flow. Spatial coverage and length of the time series will be considered to which extent stations will be included in the analysis. The zooplankton data will be examined for groups of stations at which the corresponding species behaves similarly with respect to time. Representative stations will be selected for trend analysis, rather than repeating analyses for multiple stations that show the same variability pattern. Principal Component Analysis approach will be used as described by Jassby (2003). This approach is used often in meteorology and oceanography that cover a larger-spatial scale and has been used successfully in the Delta to identify seasonal patterns and sub-regions. The starting point will be a data matrix with columns representing monthly time series of zooplankton species. The principal components of the data matrix will be calculated, and a Monte Carlo technique used to determine the number of significant components. This reduced set of important principal components is then rotated using the PROMAX method to find a new set of components with so-called simple structure, in which individual stations are associated as much as possible with a single component. The end result is a small set of rotated components representing modes of variability. The temporal variability at any given station can be thought of as a combination of these modes, with the component coefficients representing the strength of each mode for that station. To the extent simple structure is achieved, the strength for a given station will be relatively large for only one mode.

The significance of trends will be determined by using the nonparametric Seasonal Kendall test with serial correlation correction (Hirsch & Slack 1984). The overall trend slope is computed as the median of all slopes between data pairs within the same season (no cross-season slopes contribute to the overall slope estimate), known as the Theil-Sen slope.

Because freshwater flow rates likely affect seasonal long-term changes of planktonic organisms (Bennett *et al.* 2002), the influence of flow rates has to be removed to increase the power of the test. Different approaches have to be considered for this correction, such as filtering of the flow time series. Long-term trends will be estimated after adjusting for total river inflow using locally weighted regression with a span of 0.5 and a locally linear fit (see Jassby 2008).

Seasonal variability – To identify long-term seasonal trends biomass will be binned by season [summer (Jun – Aug), fall (Sept – Nov), winter (Dec – Feb), spring (Mar – May)]. For influential zooplankton species and functional groups, spatial and temporal analysis will be applied as described above. If interesting long-term changes emerge from basic seasonal trend analysis, spectral analysis will be used to detect frequency components and potential shifts in seasonality over the period of record. This will be investigated using continuous wavelet transform (Torrence & Compo 1998), which quantifies both the amplitude of any periodic signals and how this amplitude varies with time. This analysis has been used successfully in biological communities to identify fluctuations in abundances (Bjørnstad *et al.* 1999, Jenouvrier *et al.* 2005, Nezlina & Li 2007, Vasseur & Gaedke 2007, Winder *et al.* in review). For zooplankton species of concern, i.e. species that show strong declining trends and/or are major food sources for larval fish, cross-wavelet power analysis (Grinsted *et al.* 2004) will be used to explore whether the coherence in the periodicity of the population dynamics and the periodicity of phytoplankton changed over the course of the study. This will find regions in time frequency space where two time series show high common power and will identify the time periods of strong covariation between primary producers and consumers.

Modeling phytoplankton (chlorophyll) and zooplankton interactions – Phytoplankton biomass will be calculated from chlorophyll *a* measurements and zooplankton densities will be converted to biomass (see above). Long-term biotic interactions will be first examines at the annual scale between chlorophyll *a* and zooplankton biomass aggregates (influential taxa, functional groups, total biomass). These interactions will be next examined at a monthly scale. If necessary, gaps in the time series will be imputed using a time-series modeling procedure that interpolates missing values based on the autocorrelation structure in the series (as described in Jassby 2005). In addition to phytoplankton biomass environmental variables (flow rates, temperature) will be included as predictor variables.

Temperature and flow rates affect zooplankton growth performance and needs to be considered in any analysis involving seasonal changes. Biotic interactions and the importance of the predictor variables for zooplankton will be explored using time series regression models. To account for serial correlation in the residual structure autoregressive models (ARIMA) will be applied (Box *et al.* 1994). Depending on the autocorrelation structure a first-order autoregressive model, moving average process and/or seasonal autoregressive term will be applied. The seasonal structure is expected to remove the long-term trend between plankton and flow rates. The removal of serial correlation will be examined using Durbin-Watson statistic and Ljung-Box *Q*-statistics for high-order serial correlation (Shumway & Stoffer 2000).

Food-web analysis – To evaluate how changes in the plankton community relate to biotic interactions and environmental change Multivariate Autoregressive models (MAR) (Ives 1995, Ives *et al.* 1999, Ives *et al.* 2003) will be applied. MAR modeling has been developed for analyzing long-term ecological data to quantify interactions among species and environmental drivers. The models partition effects of variables that are interrelated and temporally autocorrelated, features inherent to long-term observations. Autoregressive models explicitly use correlation between time steps to improve predictions. The usefulness of MAR modeling has been effectively demonstrated with plankton community data from the North Temperate Lakes Long-Term Ecological Research program (Beisner *et al.* 2003, Ives *et al.* 2003). MAR analysis may be interpreted as a set of multiple linear regressions solved simultaneously to achieve the greatest overall parsimony. The various interacting plankton species will be aggregated into functional categories based on annual averages. Algae will be categorized based on nutrition and palatability to grazers: diatoms, phytoflagellates (including dinoflagellates, chrysophytes, and cryptophytes), chlorophytes and cyanobacteria. The categorical variables will be related to exogenous drivers such as salinity, temperature, and freshwater flow. Zooplankton will be aggregated by trophic guilds (cladocerans, herbivore copepods, omnivore copepods) and benthic larvae stages. Results from this part of the proposed work will highlight strong species interactions and potential key players through the elimination of species interactions that are too weak to predict. The success of this goal will however largely depend on the quality of the phytoplankton dataset. If outcome of this approach are promising for Delta food-web analysis it will provide a useful tool on which future modeling can be based.

Laboratory analysis: Length- weight relationships will be measured for zooplankton species from which conversion factors have not been established in the Delta. Individual species and life stages representing different length will be dried and weighted. Zooplankton species that have unknown nutritional value, essential fatty acids will be measured. Samples will be taken during Delta cruises and zooplankton separated into species and life stages/length to be analyzed. Fatty acid analysis will be conducted at UC Davis (for preparation and analysis see http://stableisotopefacility.ucdavis.edu/).

Work plan – Schedule and timeline for this project are as follows:
Year 1: Zooplankton data analysis (Objective 1) and begin analysis of phyto- and zooplankton interactions (Objective 2). Zooplankton biomass estimation and fatty acid analysis.
Year 2: Finish analysis of Objective 2 and begin analyzing food-web interactions (Objective 3). Additional zooplankton fatty acid analysis.

2c. Output, anticipated Products and Benefits

The products and services humans derive from the Delta ecosystem depend largely on how food-web structure and carbon flow changes as the ecosystem faces increasing perturbations from human activities and climate change. To restore ecosystem productivity, central of the CALFED program mission, it is important to understand pelagic food-web structure and functioning, which will ultimately determine ecosystem health and productivity. The effort invested by the IEP to document such a long, detailed, and high-quality history of the Delta ecosystem yielded insights into various estuarine ecological processes. To this end however the analysis of existing plankton data is lagging behind and the data have not yet been utilized to its full extent (Hymanson & Mueller-Solger 2001-2002, Gaines *et al.* 2006). By capitalizing on the historical planktonic record of the Delta, analyzing, synthesizing and publishing this largely unstudied community dataset, the proposed research will achieve a major IEP goal (Mount 2008) and will promote greater understanding and innovation of the Bay-Delta ecosystem.

The historical database offers a unique opportunity to use statistical and modelling tools for determining the important factors underlying plankton dynamics. As such, the proposed research will produce new conceptualizations of the Delta's pelagic food-web dynamics including new insights on *i*) spatial and temporal zooplankton variability; *ii*) dynamics and impacts of phytoplankton variation on zooplankton production; *iii*) the interactive effects of planktonic organism and environmental change. The work outlined in this proposal will build on and extend the historical knowledge that describes the dynamics of the Delta. This will provide the opportunity to quantify the causes of pelagic production, to evaluate their consequences, and find preventative measures to enable the sustainable management and conservation of the estuarine ecosystems. This information will be relevant to ecosystem management and restoration effort and will interface with different ongoing planning activates and help build an understanding of the dynamics and variability of the Delta.

The project team is fully equipped to complement the proposed research. The research mentor (G. Schladow) has worked on physical aspects in the Delta system; all community mentors (J. Cloern, A. Jassby, W. Kimmerer) have a history of productive work in the Delta, are fully engaged in ongoing research project, and have extensively worked with historical data sets, statistical and modeling tools. The agency mentor (A. Mueller-Solger) will be the main collaborator at the State agency level, and is involved in monitoring design and thus has an excellent overview of the quality, availability, and accessibility of ecological data necessary for the proposed work and ongoing research in the Delta. M. Winder will greatly benefit from this fellowship, which will provide her the opportunity to expand her long-term ecological and quantitative skills to estuarine ecosystems. She will also profit from the collaborative work with the team mentors, who collectively have tremendous knowledge about the Delta ecosystem, ecological processes, and long-term ecological data analysis. The proposed work will complement and expand on research conducted by the research and community mentors and as such this research will be instructive for their ongoing research.

The outcome of this research addresses a priority research topic of the CALFED Science Program for the California Bay-Delta system: Trends and Patterns of Habitats, Populations and System Response to a Changing Environment. Because planktonic organisms are key component in the Delta's ecosystem to restore productivity, the proposed research will bridge the CALFED mission objective to improve and increase habitats and ecological functions in the Bay-Delta to support sustainable populations of diverse species.

The results of this research will be developed into:

Year 1: *i*) Annual progress report
- *ii*) Presentations at local (Bay-Delta) and national/international professional meetings
- *iii*) Draft of first manuscript

Year 2: *i*) Annual progress and final research report summarizing results and accomplishments
- *ii*) Presentations at local (Bay-Delta) and national/international professional meetings
- *iii*) Peer-reviewed scientific publications (at least two are anticipated)

In addition, analytical tools that will emerge as most suitable for the Delta database will be provided to agency staff, who will receive training through active participation in the analysis, and recommendations based on the analysis will be provided for the ongoing monitoring program.

Figure 1. Trend statistics of different zooplankton species in the Delta between 1972 and 2001. The trend for each taxon and station is plotted at the latitude (y-axis) and longitude (x-axis) for each station. Red downward pointing triangles = decreasing trends; green upward pointing triangles = increasing trends at p<-.05; grey circles = no significant trend. Vertical line denotes the Suisun-Delta boundary. (A. Jassby, unpublished results).

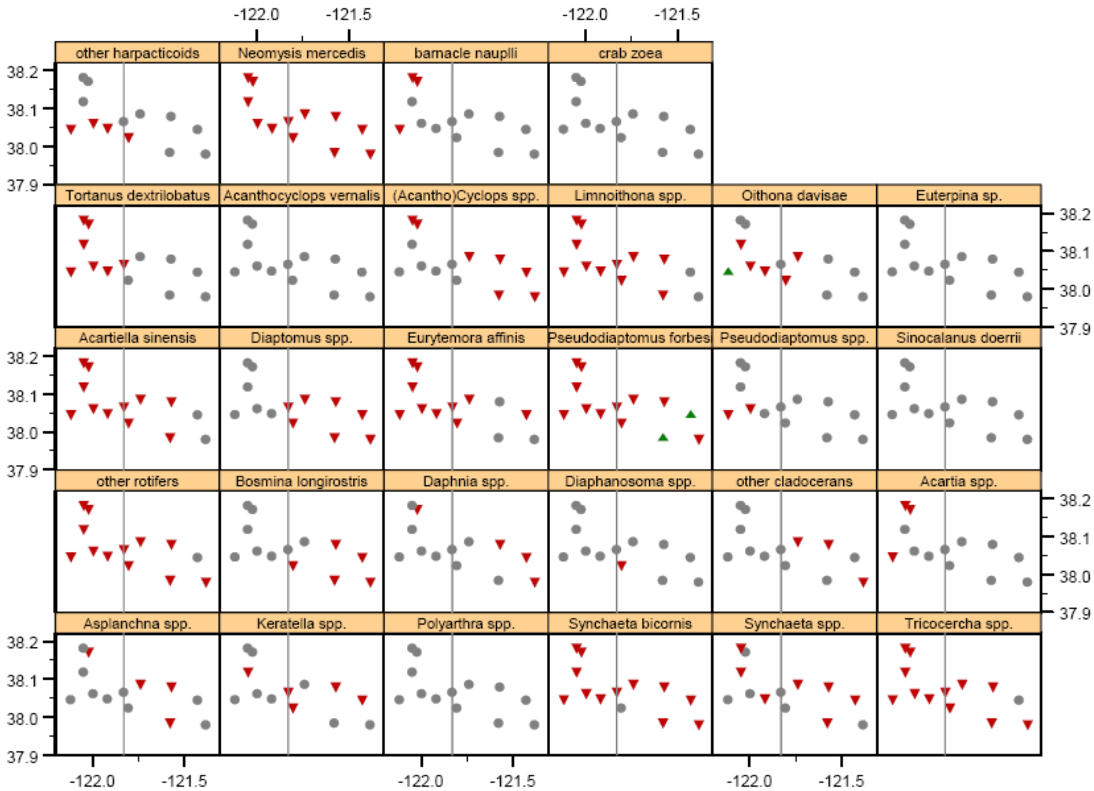

Table 1. Zooplankton species and life stages identified during in the long-term monitoring program of the Delta since 1975. In addition native vs. introduced copepod species are highlighted.

Species	Life stage	Native / Introduced	Species	Life stages
Copepoda			**Cladocera**	
Cyclopoida:			*Bosmina longirostris*	adults + juveniles
Acanthocyclops vernalis	adults	N	*Daphnia spp.*	adults + juveniles
Limnoithona spp.	adults/immatures	I	*Diaphanosoma spp.*	adults + juveniles
Oithona spp.	adults/immatures	N	*Ceriodaphnia spp.*	adults + juveniles
Oithona davisae	adults	I		
Calanoid copepod	immatures	N	**Rotifers**	
Oithona similis	adults	N	*Asplanchna spp.*	adults + juveniles
Calanoida:			*Keratella spp.*	adults + juveniles
Acartia spp.	adults/immatures	N	*Polyarthra spp.*	adults + juveniles
Acartiella sinensis	adults/immatures	I	*Synchaeta spp.*	adults + juveniles
Eurytemora spp.	adults/immatures/nauplia	I	*Synchaeta bicornis*	adults + juveniles
Euterpina acutifrons	adults	N	*barnacle nauplii*	adults + juveniles
Osphranticum labronectum	adults	I	*copepod nauplii*	adults + juveniles
Pseudodiaptomus forbesi	adults	I	*Trichocerca spp.*	adults + juveniles
Pseudodiaptomus marinus	adults	I	other Rotifers	adults + juveniles
Pseudodiaptomus spp.	adults/immatures/nauplia	N		
Sinocalanus doerrii	adults/immatures/nauplia	I		
Tortanus spp.	adults/immatures	I		
Calanoid copepod	immatures	N		
Diaptomidae		N		

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3) Budget and Budget Justification

Year 1

FISCAL YEAR Start Date: 10/1/2008 (mm/dd/yy) End Date: 9/30/2009

PROJECT NUMBER	Geoffrey Schladow NAME OF MENTOR
University of Californi INSTITUTION	Monika Winder NAME OF FELLOW

			CALFED FUNDS
A.	**EXPENDABLE SUPPLIES AND EQUIPMENT**		
	1. Computer (labtop)		3,500
	2. Monitor, docking station		1,500
	3. Software (e.g., EView, Matlab)		2,000
	4. Literature/books		1,000
	5. Laboratory and field equipment for ZP biomass estimation		1,000
		TOTAL SUPPLIES	9,000
B.	**PERMANENT EQUIPMENT**		
	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL EQUIPMENT	
C.	**TRAVEL**		
	1. DOMESTIC-U.S. AND ITS POSSESSIONS		2,000
	2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)		2,500
		TOTAL TRAVEL	4,500
D.	**PUBLICATION AND DOCUMENTATION COSTS**	TOTAL PUB COSTS	1,500
E.	**OTHER COSTS**		
	1. Fellowship Stipend (review call for proposals)		45,000
	2. Benefits Fellow @ 25 %		11,250
	3. Research Technician (SR3) @ 5 %		2,955
	4. Benefits Research Technician (SR3) @ 25 %		739
	5.		
	6.		
		TOTAL OTHER COSTS	59,944
F.	**TOTAL DIRECT COSTS** *(A THROUGH E)*	TOTAL DIRECT COSTS	74,944
G.	**INDIRECT COSTS**		
	ON CAMPUS ___ OF ___		
	OFF CAMPUS 25.0% OF 29,944		7,486
		TOTAL INDIRECT COSTS	7,486
H.	**TOTAL COSTS**	TOTAL COSTS	82,430

Prepared by:	Monika Winder	Admin Contact:	Cheryl Smith
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DATE:	6/4/08		

Year 2

YEAR 2 Start Date: 10/1/2009 (mm/dd/yy) **End Date:** 9/30/2010

	Geoffrey Schladow
PROJECT NUMBER	**NAME OF MENTOR**
University of Californi	Monika Winder
INSTITUTION	**NAME OF FELLOW**

		CALFED FUNDS
A. EXPENDABLE SUPPLIES AND EQUIPMENT		
1. Computer equipment		2,000
2. Software		1,200
3. Literature/books		1,000
4. Laboratory and field equipment for sampling and analysis		1,200
5. Fatty Acid @ $50.00/sample (UC Davis, stable isotope facility)		1,250
	TOTAL SUPPLIES	6,650
B. PERMANENT EQUIPMENT		
1.		
2.		
3.		
4.		
5.		
	TOTAL EQUIPMENT	
C. TRAVEL		
1. DOMESTIC-U.S. AND ITS POSSESSIONS		2,800
2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)		3,500
	TOTAL TRAVEL	6,300
D. PUBLICATION AND DOCUMENTATION COSTS	TOTAL PUB COSTS	2,000
E. OTHER COSTS		
1. Fellowship Stipend (review call for proposals)		45,000
2. Benefits Fellow @ 25 %		11,250
3. Research Technician (SR3) @ 5 %		2,955
4. Benefits Research Technician (SR3) @ 25 %		739
5.		
6.		
	TOTAL OTHER COSTS	59,944
F. TOTAL DIRECT COSTS *(A THROUGH E)*	TOTAL DIRECT COSTS	74,894
G. INDIRECT COSTS		
ON CAMPUS		
OFF CAMPUS 25.0% OF 29,894		7,473
	TOTAL INDIRECT COSTS	7,473
H. TOTAL COSTS	TOTAL COSTS	82,367

DATE: ____________________

Prepared by:	Monika Winder	Administrative Contact:	Cheryl Smith
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CUMULATIVE BUDGET

	Geoffrey Schladow
PROJECT NUMBER	**NAME OF MENTOR**
University of Califc	Monika Winder
INSTITUTION	**NAME OF FELLOW**
	CALFED FUNDS
A. EXPENDABLE SUPPLIES AND EQUIPMENT	15,650
B. PERMANENT EQUIPMENT	
C. TRAVEL	
1. DOMESTIC-U.S. AND ITS POSSESSIONS	4,800
2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)	6,000
D. PUBLICATION AND DOCUMENTATION COSTS	3,500
E. OTHER COSTS	119,888
F. TOTAL DIRECT COSTS *(A THROUGH E)*	149,838
G. INDIRECT COSTS	14,959
H. TOTAL COSTS	164,797

Budget Justification

Funding will support Monika Winder, who will conduct the outlined research. Since most of the proposed worked is based on data analysis, computer, software and reference literature is the major equipment cost. Some equipment cost also applies for laboratory analysis to estimate species biomass and nutritious value and 5 % for a research technician for each year, who will perform the analysis. Travel costs will be used for in-person meetings in Davis-Bay Area with the community mentors since they are located at different locations, and for local (CALFED), national and/or international workshops or conferences.

		Miles	Mil. rate	Per dim
Year 1	**Domestic travel:**			
	Davis-Tiburon-Davis; in-person meeting with metor; personal car; 6 x per year	160	0.505	42
	Davis-Menlo Park-Davis; in-person meeting with metor; personal car; 6 x per year	204	0.505	42
	Calfed Science conference; Sacramento or San Francisco; travel for 3 days plus registration			
	Subtotal domestic travel			
	International travel:			
	Science conference: ASLO; airfaire @ 1500; registration + lodging			
	Subtotal international travel			
	Travel total Yr 1			
Year 2	**Domestic travel:**			
	Davis-Tiburon-Davis; in-person meeting with metor; personal car; 8 x per year	160	0.505	42
	Davis-Menlo Park-Davis; in-person meeting with metor; personal car; 9 x per year	204	0.505	42
	Calfed Science conference; Sacramento or San Francisco; travel for 3 days plus registration			
	Subtotal domestic travel			
	International travel:			
	Science conference: not yet determined			
	Scientific workshop: not yet determined			
	Subtotal international travel			
	Travel total Year 2			

Costs
737
870
393
2000
2500
2500
4500
982
1305
512
2800
2500
1000
3500
6300

Monika Winder, Calfed Science Fellowship 2008

Travel justification:

		Miles	Mil. rate	Per dim	Costs
Year 1	**Domestic travel:**				
	Davis-Tiburon-Davis; in-person meeting with metor; personal car; 6 x per year	160	0.505	42	737
	Davis-Menlo Park-Davis; in-person meeting with metor; personal car; 6 x per year	204	0.505	42	870
	Calfed Science conference; Sacramento or San Francisco; travel for 3 days plus registration				393
	Subtotal domestic travel				**2000**
	International travel:				
	Science conference: ASLO; airfaire @ 1500; registration + lodging				2500
	Subtotal international travel				**2500**
	Travel total Yr 1				4500
Year 2	**Domestic travel:**				
	Davis-Tiburon-Davis; in-person meeting with metor; personal car; 8 x per year	160	0.505	42	982
	Davis-Menlo Park-Davis; in-person meeting with metor; personal car; 9 x per year	204	0.505	42	1305
	Calfed Science conference; Sacramento or San Francisco; travel for 3 days plus registration				512
	Subtotal domestic travel				**2800**
	International travel:				
	Science conference: not yet determined				2500
	Scientific workshop: not yet determined				1000
	Subtotal international travel				**3500**
	Travel total Year 2				6300

4) Explanation of how Research Links to the CALFED Program

The proposed study is central to the *CALFED* mission to '*develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System*'. A richer understanding of ecological processes will be critical for the success of this CALFED goal. Long-term observations of ecological variables provide a unique opportunity to understand underlying processes for ecosystem dynamics. As such, the proposed research will largely contribute to better understand processes that affect population dynamics at the base of the pelagic food web, the primary energy source for upper trophic levels. Retrospective analysis is the best way to learn how future changes may alter the Bay-Delta system and thus the proposed research will largely improve our predictive capabilities for this ecosystem.

In addition, several ongoing Delta activities will benefit from the outcome of the proposed research, such as the *Pelagic Organism Decline* (POD) work team. This team was formed by the Interagency Ecology Program (IEP) in response to the recent marked declines in four pelagic fish species in the Delta-Bay to evaluate the potential causes. The conceptual model is rooted in classical fisheries food web ecology and identified the four major components (1) prior fish abundance, (2) habitat quality, (3) top-down effects, and (4) bottom-up effects. The proposed research will bridge two of the four identified key components: habitat quality and bottom-up processes. The long-term and recent status and dynamics of the major food source for fish species of concern are at this point poorly understood. As such, the proposed research will be an essential component for the POD and will help to interpret how changes in the food source for fish contributed to long-term and more recent declines. In addition, the proposed research will provide information about food-quality for primary and secondary consumers, which will be an important indicator of habitat quality. The outcome of the outlined research will be particularly informative for the POD working group and will allow to extent the food-web model to biotic interactions at the base of the Delta food web.

The proposed research will also interact with restoration and management activities in the Delta, including the *Delta Regional Ecosystem Restoration Implementation Plan (DRERIP)* that applies an adaptive management approach by developing a suite of ecosystem conceptual models and life history models. The proposed study will expand on the ecosystem conceptual model and will provide useful information on spatial food-web dynamics at the base of the Delta food web. This information will be useful for future planning and restoration actions and will identify areas that need additional research. Because the energy pathway through the phytoplankton-zooplankton link largely fuels upper trophic levels in the Bay-Delta, this study will be informative for the *Delta Vision* and Bay-Delta Conservation plan to identify a strategy for managing the Delta as a sustainable ecosystem that supports environmental and economic functions.

Finally, reviews of the *IEP monitoring program* (e.g., environmental monitoring program, delta smelt review) and the *CALFED Independent Science Board* agreed that tremendous data collection efforts in the Bay-Delta are accomplished. However, they also comment on improving the utilization of the existing data since the analysis is often lagging behind. The proposed study will address this recommendation by analyzing, synthesizing, and publishing an extraordinary record of ecological data.

5) Personal Statement

My general research activities are focused on understanding the causes and consequences of dynamics in aquatic ecosystems, and particularly in understanding (1) The effect of environmental change on ecosystem processes, species dynamics, and community composition; (2) Behavioral and life-history adaptation to environmental variation; (3) Nutrients and food-web dynamics in aquatic systems; and (4) Modeling approaches for predicting environmental changes on ecosystems dynamics. I use a multi-disciplinary approach, combining descriptive field studies and experimental research (field and laboratory) with statistical modeling to relate external variations on ecosystem dynamics and species responses. While my research topics are general in ecology, I address my questions in aquatic systems with a special emphasis on planktonic organisms.

During my training phase and scientific career I have participated in diverse ecological research activities: my master thesis focused on documenting benthic responses to re-oligotrophication; my dissertation sought to investigate the impacts of environmental variation on plankton behavior and life histories in alpine lakes; my postdoctoral work at the University of Washington investigated climate change impacts on aquatic processes and particularly on climate effects phenology, food-web interactions and temporal population dynamics of effects of species with a complex life cycle. In another project area, I characterized the effects of marine-derived nutrients on freshwater ecosystem production in streams in Alaska and participated in coring of various remote Alaskan lakes. I was further involved in an international project to analyze recovery patterns in lakes undergoing reduction of anthropogenic nutrient loadings, and in characterizing impacts of habitat structure on fish-plankton dynamics.

My current projects at the University of California include the investigation of bio-physical interactions, particularly in mixing effects on phytoplankton community dynamics, molecular identity and dynamics of natural picophytoplankton communities, UV effects on phytoplankton community structure, and food-web analysis. I also participate in establishing a world lake data base for estimating global lake productivity; and in developing a multi-nation research effort that aims to understand Pacific Ocean climate effects on inland water bodies on the Pacific Rim.

My research emphasized the importance of environmental variation on food-web dynamics and gave me a solid background in field methodology, experimental design, statistical analysis as well as modeling techniques useful in ecology. During my most recent years my work focused on long-term ecological research and historical data analysis to understand how climate change and environmental impacts affect population and community dynamics. I have worked on long-term monitoring datasets from different lake systems. The nature of the proposed research builds upon my past and present research and will benefit form my ecological and quantitative skills. Several models and statistical techniques applied in my past research can be applied for different research questions and systems. The proposed project will complement this and moreover will give me the opportunity to expand my knowledge on ecosystem functioning and structure of estuarine ecosystem.

One important observation during my past research was that environmental change and human activities strongly affect the function and structure of food webs by altering physical, chemical, and biological processes of ecosystems. I believe that it is an increasing call for ecologists to improve our understanding of the extent and magnitude of such alterations on ecosystems. In uncertain environments the past give us the opportunity to reflect upon and learn from ecosystem alterations. Historical records tell us that environments and ecosystems can change in unpredictable and abrupt ways. Historical data analysis provides a unique tool to investigate how environmental changes affect ecosystem dynamics at different time scale and to determine underlying processes, which will help us to predict impacts of future change. The work I am proposing will provide essential insight in such processes and takes full advantage of the knowledge and skills I gained during the training phase of my career.

I foresee to continue working in environmental research and expand in understanding how environmental change affect ecosystem function and structure by combining long-term observations, experimental research and modeling. The *CALFED fellowship* grant will enable me to continue working on this research topic and will provide the transitional funds necessary to expand into a different ecosystem. Most of my training was in freshwater systems; however I intend to integrate different systems in my research and look at processes across fresh and saline systems. While the physical structure varies between estuarine systems and freshwater systems, both systems have same taxonomic and functional groups at the lower base of the food web. Thus similar mechanisms are expected in both systems that operate to transmit energy through the plankton food web. In a future step I would like to integrate different aquatic systems (marine, estuarine, lakes) to gain knowledge about their similarities and features specific to each system. Thus expanding into estuarine ecosystems will be advantageous for my future career goals.

I am very motivated to collaborate with the research and community mentors on this research topic in the Delta because I believe that collectively we bring together tremendous complementary knowledge from different discipline, including quantitative, ecological, and experimental skills. Thus, I am looking forward for fruitful collaborations and successful research outcomes. In summary, this activity will be beneficial for my ecological understanding and develop professional relationships that will equip me to work collaboratively within interdisciplinary groups. It will also expand my investigative vision and critical thinking and give me insight in policy development and ecosystem management and restoration. Overall the *CALFED fellowship* will equip me with necessary tools to embark on my next scientific venture.

MONIKA WINDER

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EDUCATION

Ph.D., Natural Sciences, ETH (Swiss Federal Institute of Technology), Zürich, Switzerland, Department of Limnology, EAWAG, 1998 – 2002. Dissertation: *Zooplankton ecology in high-mountain lakes*. Doctoral committee: Prof. J.V. Ward, PD Dr. P. Spaak, Prof. W. Lampert.

M.Sc., Zoology, University Innsbruck, Innsbruck, Austria, Department of Zoology, Institute of Limnology, 1991 – 1997. Thesis: *Distribution patterns of benthic crustaceans in a lake with changing trophic conditions.* Advisors: Prof. R. Psenner, Dr. L. Füreder.

M.Sc., Biology Education, University Innsbruck, Innsbruck, Austria, Department of Biology, 1991 - 1997

Graduate studies in Biological Sciences, University of New Orleans, New Orleans, USA, 1996

RESEARCH INTERESTS

Areas of research specialization include: aquatic ecology, plankton ecology, food-web dynamics, climate impact research, long-term ecological research, biodiversity, ecosystem research, trophic interactions, community ecology.

RESEARCH EXPERIENCE

Visiting Scientist, Ocean Sciences, University of California, Santa Cruz, May 2006-present:
Enumeration and molecular identification of autotrophic picoplankton

Visiting Scientist, Swiss Federal Institute of Aquatic Science and Technology, Nov-Dec 2006.

Research Associate, University of California, Davis, John Muir Institute of the Environment, Tahoe Environmental Research Centre, 2005 – present:
Linkages between physical processes and plankton community structure

Post-doctoral Fellow, University of Washington, Seattle, School of Aquatic and Fishery Sciences and Department of Biology, 2002-2005:
Ecosystem responses to environmental change

Doctoral Student Researcher, EAWAG/ETH, Switzerland, 1998 – 2002:
Food-web dynamics in plankton

Visiting PhD student, Max-Planck-Institute for Limnology, Plön, Germany, 2001:
Diel vertical migration of plankton – an experimental approach using Plankton Towers

Graduate Research, Department of Zoology, University Innsbruck, 1995-1997:
Distribution patterns of benthic crustaceans

Graduate Research, Department of Zoology, University Innsbruck, 1996:
Studies of tropical streams in Costa Rica

Graduate Research, Department of Zoology, University Innsbruck, 1995:
Changing abiotic and biotic conditions in tidal marine rock pools (Rovinj, Croatia).

Research Technician, Arge Limnologie, Innsbruck, Austria, 1995–1996:
Macrozoobenthos identification

RESEARCH GRANTS

University of California, Pacific Rim Research Program, Workshop grant for initiating research on '*Climate impacts on lakes of the Pacific Rim*', 2007 – 2008

Austrian National Science Foundation (FWF), Postdoctoral research grant, 2003 – 2004

Swiss National Science Foundation (SNF), Postdoctoral research grant, 2002 – 2003

RESEARCH FELLOWSHIPS & AWARDS

Training course in Antarctic Biology, NSF, Jan 2008 (upcoming): *Integrative Biology and Adaptation of Antarctic Marine Organisms*

Deutscher akademischer Austauschdienst (DAAD), research grant, 2001

Best Student Poster, Symposium for European Freshwater Sciences, Antwerp, Belgium, 1999

Austrian Federal Fellowship, Grant for studies in a foreign country, 1996

Vorarlberger Fellowship, Grant for abroad studies and research, 1996

Austrian Federal Fellowship, Grant for excellent studies, 1993, 1995

TEACHING EXPERIENCE

Lecturer, University of California, Davis, 2008

Guest Lecturer, University of Washington, 2002-04 and University of Davis 2007-08:
Limnology

Teaching Assistant, ETH Zürich, Switzerland, 1998-2001:
Physics for Biology, Ecological Genetics, General and Applied Limnology, Introduction to data management programs

Teaching Assistant, University of Innsbruck, Innsbruck, Austria, 1998–2000:
Zooplankton Ecology

High School Teacher, Public and Private High School, Innsbruck, Austria, 1994–1998:
Biology, Chemistry

PUBLICATIONS

<u>Winder M</u>, Hunter DA (2008) Temporal organization of phytoplankton communities linked to chemical and physical forcing. *Oecologia*. 156: 179–192.

Kamenir Y, <u>Winder M</u>, Dubinsky Z, Zohary T, Schladow G (in press) Lake Tahoe vs. Lake Kinneret phytoplankton: comparison of long-term taxonomic size structure consistency. *Aquatic Sciences*.

Shurin JB, Arnott SE, Hillebrand H, Longmuir A, Pinel-Alloul B, <u>Winder M</u>, Yan ND (2007) Diversity-stability relationship depends on latitude in zooplankton. *Ecology Letters*, 10: 127-134.

<u>Winder M</u>, Schindler DE, Moore JW, Johnson SP, Palen WJ (2005) Do bears facilitate transfer of salmon resources to aquatic macroinvertebrate? *Canadian Journal of Fisheries and Aquatic Sciences,* 62: 2285-2293.

Jeppesen E, Sondergaard M, Jensen AP, Havens K, and 27 others (2005) Lakes' response to reduced nutrient loading - an analysis of contemporary data from 35 European and North American long term studies. *Freshwater Biology,* 50: 1747-1771.

<u>Winder M</u>, Schindler DE (2004) Climate change uncouples trophic interactions in a lake ecosystem. *Ecology*, 85: 2100–2106.

Winder M, Schindler DE (2004) Climatic effects on the phenology of lake processes. *Global Change Biology*, 10: 1844–1856.

Arhonditsis GB, Winder M, Brett MT, Schindler DE (2004) Uncovering patterns and mechanisms of phytoplankton variability in Lake Washington. *Water Research*, 38: 4013–4027.

Winder M, Spaak P, Mooij WM (2004) Trade offs in *Daphnia* habitat selection. *Ecology*, 85: 2027–2036.

Winder M, Bürgi HR, Spaak P (2003) Factors regulating zooplankton succession in a high-mountain lake. *Freshwater Biology*, 48: 795-809.

Winder M, Boersma M, Spaak P (2003) On the cost of vertical migration: are feeding conditions really worse at deeper depth? *Freshwater Biology*, 48: 383-393.

Winder M, Spaak P, Buergi HR (2003) Seasonal vertical distribution of phytoplankton and copepods in a high-mountain lake. *Archiv für Hydrobiologie*, 158: 197-213.

Winder M, Spaak P (2002) Effects of natural UV radiation on the life history of alpine *Daphnia*. *Verhandlungen Internationale Vereinigung für theoretische und angewandte Limnologie*, 28: 355-359.

Winder M, Monaghan MT, Spaak P (2001) Have human impacts changed alpine zooplankton diversity over the past 100 years? *Arctic Antarctic and Alpine Research*, 33: 467-475.

Winder M, Spaak P (2001) Carbon as an indicator of *Daphnia* condition in an alpine lake. *Hydrobiologia*, 442: 269-278.

Winder M, Pehofer HE, Füreder L (2000) Distribution patterns of benthic crustaceans in a formerly meromictic lake with changing trophic conditions (Lake Piburg, Tyrol, Austria). *Archiv für Hydrobiologie*, 147: 519-533.

PUBLICATIONS IN REVIEW

Winder M, Schindler DE, Essington TE, Litt AH, Edmondson, WT (in review) Environmental effects on copepod voltinism and population dynamics. *Global Change Biology*.

Romare P, Winder M, Schindler DE (in review) Does shoreline development lead to decreased fish activity in spring?

Hunter DA, Winder M, (in review) Long-term changes of the chrysophyte population in Lake Tahoe. *Verhandlungen Internationale Vereinigung für theoretische und angewandte Limnologie*, 28: 355-359.

PUBLICATIONS IN PROGRESS

Finger D, Winder M, Schladow SG (in prep.) A numerical model to determine environmental effects on primary production in Lake Tahoe. (To be sent to *Water Resource Research*).

Winder M (in prep.) Climate warming selects for small-sized diatoms. (To be sent to *Proceedings of the Royal Society B*).

Winder M (in prep.) Autotrophic picoplankton in Lake Tahoe: Establishing their sensitivity to external forces. (To be sent to *Limnology & Oceanography*).

Winder M, Schindler DE (in prep.) Cyclic modes of climate variability: a guide for ecologists.

Rose K, Williamson C, Winder M, Schladow G (in prep.) Patterns of spatial and temporal variability of UV and PAR transparency in Lake Tahoe, Ca/NV. (To be sent to *Journal of Geophysical Research*)

Book Contribution

Winder M (2006) Sunfishes. In: *Invasive Species in the Pacific Northwest*. Boersma DP, Reichard SH, Van Buren AN (eds). The University of Washington Press, Seattle and London.

Popular Articles

Spaak P, Engeler L, Winder M (2004) Überlebensstrategien der Wasserflöhe in Bergseen: Störfaktor Mensch (Survival strategies of water fleas in alpine lakes). *Cratschla* 2: 21-23.

Winder M, Spaak P (2003) Genetische Diversität von *Daphnien* in alpinen Seen (Genetic diversity of *Daphnia* in alpine lakes). *EAWAG News* 56:22-23.

Winder M, Spaak P (2001) Der Einfluss von Umweltfaktoren auf die Vertikalwanderung von *Daphnien* in Bergseen (The effects of environmental factors on the diel vertical migration of *Daphnia* in alpine lakes). *EAWAG Annual Report*.

Winder M (2002) Limnologisches Projekt am Obersee abgeschlossen (Limnological project at the Obersee is finished). *Arosa Zeitung*, Local newspaper.

Winder M (2000) Riesen ‚Experimentgläser' im Obersee (Enormous 'experimental tubes' in the Obersee). *Arosa Zeitung,* Local newspaper.

Winder M, Lass S, Spaak P, Bürgi HR (1999). Einfluss von Fischkairomonen auf die Vertikalwanderung von *Daphnien* (The influence of fish kairomones on *Daphnia* vertical migration). *EAWAG Annual Report*.

Winder M (1999) Wieviel Enten verträgt der Obersee? (How many ducks can the Obersee tolerate?) *Arosa Zeitung*, Local newspaper.

Winder M (1998) Limnologisches Projekt am Aroser Obersee (Limnological project at the Aroser Obersee). *Arosa Zeitun*g, Local newspaper.

Media Outreach – Features About My Research

Print The Seattle Times (June 22, 2005) (http://seattletimes.nwsource.com/html/home/)

Seattle Post-Intelligencer (July 11, 2005) (http://seattlepi.nwsource.com/local/232047_lakewash11.html)

Der Standard (http://derstandard.at/Text/?id=2365726)

Chesapeake Quarterly (http://www.mdsg.umd.edu/CQ/V05N3/side1.html)

Radio National Public Radio, Puget Sound (July 12, 2004)

Invited Seminars & Presentations

Chapman Conference on Lakes as Sentinels, Integrators, and Regulators of Climate Change; Keynote speaker, USA, Sept 2008 (upcoming).

Romberg Tiburon Center for Environmental Studies, Tiburon, CA, Feb 2008.

Austrian Academy of Sciences, Institute of Limnology, Mondsee, Austria, Oct 2007.

Imperial College of London, UK, Department of Biological Sciences, Nov 2006.

Simon-Fraser University, Department of Biological Sciences, Burnaby BC, May 2006.

University of Washington, School of Aquatic and Fishery Sciences, Feb 2006.

ETH-EAWAG (Swiss Federal Institute of Aquatic Science and Technology), Switzerland, Department of Limnology, Jul 2005.

Alaska Fisheries Science Center, NOAA-NMFS, Hatfield Marine Science Center, Newport, OR, May 2005.

Florida Atlantic University, Davie, FL, Apr 2005.

ASLO (American Society of Limnology and Oceanography), Salt Lake City, UT, Feb 2005.

Michigan State University, Kellogg Biological Station, MI, Jan 2005.

University of Warschau, Poland, Jan 2001.

PRESENTATIONS AT SCIENTIFIC MEETINGS

Winder M. Picophytoplankton dynamics in Lake Tahoe: establishing their sensitivity to external forces. Society of International Limnology, Montreal, Canada, 2007.

Winder M, Reorganization of phytoplankton communities linked to physical forcing. Ecological Society of America, San Jose, CA, 2007.

Winder M, Hunter D., Schladow G. Phytoplankton community responses to physical forcing in Lake Tahoe. ASLO, Victoria, 2006.

Winder M, Essington TE, Litt AH, Schindler DE. Climatic effects on copepod population dynamics. ASLO, Salt Lake City, 2005.

Winder M, Essington TE, Litt AH, Schindler DE. Climatic effects on *Leptodiaptomus* population dynamics. ESA, Portland, OR, August 2004.

Winder M, Schindler DE. Climatic effects on trophic interactions in aquatic ecosystems. Climate change and aquatic ecosystems, Plymouth, UK, July 2004.

Winder M, Schindler DE, Hampton SE. Climate impact on the phenology of lake processes. ASLO, Salt Lake City, UT, February 2003.

Winder M, Schindler DE. Aquatic responses to environmental changes in Lake Washignton, LIMPACS workshop, Silkeborg, Denmark, January 2003.

Winder M, Spaak P. Local adaptation of alpine zooplankton. ESEB, Aarhus, Denmark, August 2001.

Winder M, Spaak P. Diel vertical migration: not a predator avoidance strategy in alpine lakes? SIL Congress, Melbourne, Australia, February 2001.

Winder M, Spaak P. Occurrence and clonal variation of *Daphnia* in Alpine lakes. International Symposium: High mountain lakes and streams: indicators of a changing word, Innsbruck, Austria, September 2000.

Winder M, Spaak P. Behavioural adaptation of *Daphnia galeata* to changing fish biomass in an alpine lake. 6th Annual Meting of Ph.D. Students in Evolutionary Biology, Leuven, Belgium, February 2000.

Winder M, Spaak P, Bürgi HR. Diel vertical migration of daphnids in relation to changing fish biomass in an alpine lake. ASLO, Kopenhagen, Denmark, June 2000.

Winder M, Bürgi HR, Spaak P. The influence of diel vertical migration on the condition of daphnids in an alpine lake. International Symposium on Cladocera, Plön, Germany, September 1999.

Winder M, Spaak P, Bürgi HR. Diel vertical migration of *Daphnia* in relation to fish biomass and food distribution in an alpine lake. Symposium for European Freshwater Sciences, Antwerp, Belgium, August 1999.

SERVICES

Undergraduate advisor: ETH, Switzerland, 2000 – 2002.

Graduate student and postdoctoral advisor: University of Washington, University of California, 2002 – present.

Societies: American Society of Limnology and Oceanography (ASLO), Ecological Society of America (ESA), Society of International Limnology (SIL).

Reviewer: Ecology Letters, Ecology, PNAS, Limnology and Oceanography, Oecologia, Proceedings of the Royal Society B, Freshwater Biology, Hydrobiology, Journal of Plankton Research, Limnology and Oceanography: Methods, Functional Ecology, Aquatic Sciences, Canadian Journal of Aquatic and Fishery Sciences, Australian Ecology, Journal of the North American Benthological Society.

Editorial Board: Journal of Plankton Research.

REFERENCES

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7) Plan for Collaborating with Community Mentors

The community mentors for the proposed research include Dr. Alan Jassby (UC Davis), Dr. James Cloern (USGS), Dr. Wim Kimmerer (SFU), and Dr. Anke Mueller-Solger (DWR). All of them have worked extensively in the San Francisco Bay-Delta ecosystem:

Dr. Alan Jassby is a Research Ecologist with the Department of Environmental Science and Policy at the University of California at Davis. He has worked on a variety of issues in aquatic ecology in different systems across lakes, estuaries and oceans. His current work focuses on understanding year-to-year and longer-term change in aquatic ecosystems. He worked extensively with the long-term data set of the Bay-Delta and applying various quantitative approaches to understand ecosystem dynamics and functioning in the Bay-Delta, which produced great insight into ecosystem functioning. He is an expert in analyzing long-term ecological data and well-informed with various statistical and modeling tools that will be applied in the proposed study. Dr. Jassby will also provide great insight into the quality of the long-term dataset since he worked with most of the variables that will be used in the outlined research. He will be the major mentor in implementing quantitative and modeling approaches, data quality control, and in coordinating research planning.

Dr. James Cloern is an aquatic ecologist with the USGS and conducted research in lakes, streams, and estuaries, using field measurements and numerical modeling to identify the patterns and mechanisms of ecosystem variability. He is the leader of the USGS team that collects water quality measurements in San Francisco Bay. His research interests include (1) distribution, abundance, species composition, and productivity of planktonic microalgae, animals, and bacteria in estuaries; (2) understanding processes that regulate population dynamics and productivity of planktonic organisms in estuaries; (3) define and quantify processes through which the plankton alter and reflect water quality in estuaries; (4) define and quantify benthic processes that affect plankton dynamics and productivity of estuaries; and, (5) define anthropogenic impacts on estuarine ecosystems. Dr. Cloern has conducted research in the Bay-Delta over the last decades and is very knowledgeable with ecological functioning and processes. He will be a major collaborator for numerical modeling and understanding ecological processes. The proposed research bridges with his ongoing work in the Bay-Delta and thus will provide ample opportunities for collaborations.

Dr. Wim Kimmerer is a researcher at the Romberg Tiburon Center with a background in chemistry and biological oceanography. Most of his research is connected within the aquatic ecosystem of the San Francisco Estuary. His current research interests include zooplankton ecology, the ecology of estuaries with an emphasis on San Francisco Bay, and the use of models in aquatic ecology. His research focuses on several topics that interact with the proposed research, such as interactions between physical dynamics of the estuary and the distribution and dynamics of planktonic organisms, the foodweb supporting delta smelt and other fish of the upper estuary, or effects of introduced species. Dr. Kimmerer will be the main contact person for understanding food-web interactions and implementing the trophic structure/functional groups in the data analysis. The proposed research will complement his experimental research in the Delta ecosystem and with his expertise in trophic interactions he will contribute greatly to the proposed work.

Dr. Anke Mueller-Solger is a researcher at the Department of Water Resources and will be the main collaborator at the State agency level. She is involved in monitoring design and thus has an excellent overview of the quality, availability, and accessibility of ecological data necessary for the proposed work. She is also deeply engaged with the Pelagic Organism Decline working group and has experience at the Department of Water Resources, IEP, and CALFED. In addition she has a great understanding of various ongoing research projects in the Bay-Delta and thus will be able to provide great insight in ecosystem functioning. She will provide necessary logistical and data support and serve as a liaison between the IEP and the work team.

The community mentors will contribute fruitfully to approach the proposed research questions. The expertise and insight of the team members will be exchanged in regular meetings, emails, and phone communications. These communications will also be used to coordinate the planned research, discuss quality of existing monitoring data, and talk about ongoing projects in the Delta and estuarine ecology. Contacts with these community mentors will be useful for research suggestions and explanations within the Delta and on how to contribute best to ongoing and future Bay-Delta research and management. These collaborations will also open doors to connect with other academic and agency scientists working in the Bay-Delta system.

In summery, the research team brings together tremendous knowledge about ecosystem functioning and dynamics in the Bay-Delta and numerical approaches to analyze long-term ecological data. Thus, all the ingredients are in place for highly productive research outputs.

CALFED Project Summary Form - California Sea Grant

Title: Plankton dynamics in the Sacramento– San Joaquin Delta: Long-term trends and trophic interactions

Type of Fellowship: Postdoctoral

Initiation Date: 10/01/2008

Completion Date: 09/30/2010

	Last	First	Initial		
CALFED Fellow:	Winder	Monika		**Effort:**	
Affiliation:	University of California, Davis			**Affil. Code:**	
Research Mentor 1:	Schladow	Geoff		**Effort:**	
Affiliation:	University of California, Davis			**Affil. Code:**	
Research Mentor 2:				**Effort:**	
Affiliation:				**Affil. Code:**	
Community Mentor 1:				**Effort:**	
Affiliation:				**Affil. Code:**	
Community Mentor 2:				**Effort:**	
Affiliation:				**Affil. Code:**	

Total CALFED Funds: 164,707

Related Projects:

Parent Projects:

Key Words:

Objectives:

Primary consumers (zooplankton) are a critical trophic link for energy transfer to upper trophic levels and a key food source for threatened and endangered fish species in the Delta. Yet long-term trends and patterns for zooplankton and mechanisms that regulate their abundances remain largely unstudied despite the fact that the importance of food availability for fish has been recognized as one potential major component for the observed fish declines and a taxonomically-rich historical plankton data set exists. Because the zooplankton community is vital for ecosystem productivity at higher trophic levels, it is timely to take advantage of this historical data resource to understand longterm variability and processes underlying changes in zooplankton. The proposed research aims to identify spatial and temporal plankton variability and biotic interactions by quantitatively analyzing the long-term database from the Delta, which has a 33-year record related to the planktonic food web along with complementary environmental data. The proposed project will address the following objectives:

(1) Identification of long-term spatial and temporal patters in zooplankton
(2) Identifying long-term interactions between primary producers and zooplankton
(3) Identification of biotic interactions in the plankton community

We propose that through integrating plankton variability into the management and restoration plan for the Delta, the dynamics of the ecosystem can be viewed from a new perspective that has key implications for understanding the decline in pelagic organisms. The outcome of this analysis will be instructive to understand to what extent variability and shifts in zooplankton forage for fish affect pelagic productivity and as such is central to the CALFED mission.

Methodology:

by the California Departments of Water Resources and Fish and Game, collected at about monthly intervals. To address the proposed objectives quantitative analysis that have been used successfully in the Bay-Delta and other aquatic systems will be applied:

Trend analysis –The temporal dynamics of zooplankton will be characterized using single taxon abundances of influential community members and aggregate community properties (functional groups based on trophic level and nutritional value for fish forage). Densities will be converted to biomass to reflect the true contribution of individual species to total composition. Long-term trends will be analyzed for each stations and Principal Component Analysis will be used to identify subregions with similar trajectories. The significance of trends will be determined by using the nonparametric Seasonal Kendall test with serial correlation correction.

Seasonal variability – Spectral analysis will be used to detect frequency components and potential shifts in seasonality over the period of record using continuous wavelet transform. For zooplankton species of concern, cross-wavelet power analysis will be used to explore whether the coherence in the periodicity of the population dynamics and the periodicity of phytoplankton changed over the course of the study.
Modeling phytoplankton (chlorophyll) and zooplankton interactions – Phytoplankton biomass will be calculated from chlorophyll measurements and zooplankton densities will be converted to biomass and categorized according to functional groups. Long-term biotic interactions will be examines at annual and monthly scale. Biotic interactions and the importance of the predictor variables for zooplankton will be explored using time series regression models (ARIMA).

Food-web analysis – A quantitative multivariate analysis approach will be applied to investigate interactions between phytoplankton functional groups based on their nutritional value and zooplankton aggregates to evaluate how changes in the plankton community relate to biotic interactions and environmental change. Multivariate Autoregressive models will be applied, which have been developed for analyzing interactions using long-term data.

In addition to quantitative analysis, density-biomass conversion factor and essential fatty acids (as an indicator for zooplankton nutritional value) will be measured for zooplankton species from which these values are unknown.

Rationale:

Past analysis of the long-term ecological database of the Delta provide useful insight in the dynamics and processes that regulate population dynamics of pelagic organisms. These analyses concentrated on identifying patterns in abiotic factors, phytoplankton biomass and pelagic fish organisms. However detailed zooplankton patterns and quantitative food-web linkages remain largely unstudied, although zooplankton is the primary food source for fish species of concern. The proposed study will fill the gap of knowledge in spatial and temporal patterns and trends in zooplankton and species interactions at the base of the Delta's food web.

Objective 1 will identify long-term zooplankton temporal patterns at Delta wide scale and will identify sub-regions that have experienced similar zooplankton trajectories. Spatial interannual and seasonal population dynamics will be examined using zooplankton taxa and zooplankton functional groups according to their feeding ecology (trophic level) and nutritional value as a food source for fish. Distinguishing different functional groups will be important because zooplankton community changed vastly due to species introduction and displacement, and will be indicative of forage quality for fish species. This objective will address a first critical step to identify spatial long-term and seasonal zooplankton dynamics. Shifts in zooplankton population dynamics and species displacement may result in a mismatch between food availability for fish species relative to fish growth performance.

In Objective 2 the trophic linkage between primary producers, primary consumers and environmental variables will be analyzed to understand to what extent phytoplankton variability affects zooplankton production. Primary producers showed an overall long-term declining trend, however recovered over the last decade. This suggests that while reduced primary production was likely the cause for the earlier decline, recent decline in zooplankton abundances can not be attributed to change in primary production. This discrepancy could be attributed to species displacements that utilize other resources such as microzooplankton. Besides food availability, it will also be examined how change in environmental factors such as flow rates and temperature affect zooplankton dynamics. This part of the project will identify temporal coherence of primary producers and zooplankton population dynamics of single taxa and zooplankton functional aggregates.

Objective 3 will identify in more detail biotic interactions and environmental variability by focusing on functional phytoplankton and zooplankton groups to account for change in plankton species composition. Such a cohesive foodweb analysis of the long-term data that includes different phytoplankton and zooplankton functional groups is still lacking in the Delta. The algal taxonomic composition is informative for the nutritional value for primary consumers and change in food quality is another possibility why recent recovery of phytoplankton biomass did not translate into increasing production of primary and secondary consumers. Therefore, algal quality should be considered to fully understand the underlying processes that limit zooplankton production. In addition to biotic interactions, changes in exogenous drivers will be considered. These results will identify major species interactions and energy pathways to upper trophic levels and pathways through which abiotic variables may act on communities.

Anticipated accomplishments:

The accomplishments of the proposed research will help to improve our knowledge about ecological processes underlying the decline of pelagic organisms. It will produce new conceptualizations of the Delta's pelagic food-web dynamics including new insights on i) spatial and temporal zooplankton variability; ii) dynamics and impacts of phytoplankton variation on zooplankton production; iii) the interactive effects of planktonic organism and environmental change. The research team brings together tremendous knowledge about ecosystem functioning and dynamics in the Delta and numerical approaches to analyze long-term ecological data. Thus, all the ingredients are in place for highly productive research outputs. Research results will be developed into reports and peer-reviewed scientific publications and will be presented at local and international meetings. In addition, analytical tools that will emerge as most suitable will be provided to agency staff. The work outlined in this proposal will build on and extend the historical knowledge that describes the dynamics of the Delta. This analysis will produce important input for various Delta planning activities to increase pelagic productivity, including the Action Plan for Pelagic Organisms Decline, Delta Vision, or the Delta Regional Ecosystem Restoration Implementation Plan.

June 6, 2008

To Whom It May Concern:

RE: Letter of committment for Monika Winder

This letter is to affirm my commitment to mentor Monika Winder for her research on "Plankton dynamics in the Sacramento−San Joaquin Delta: Long-term trends and trophic interactions". I have been acting as Dr Winder's faculty mentor for the last 2.5 years, during which time she has been working on examining the long term data set for Lake Tahoe, as well as conducting experiments on zooplankton response to environmental conditions. Dr Winder is a highly effective researcher, with a broad range of skills and a very deep level of curiosity. She has all the makings of a fine researcher or faculty member.

I am also totally in support of the proposed research project, and could not think of anybody better qualified to undertake this important task. Dr Winder has already proven more than capable of bringing together long term, imperfect data sets at two very different locations – Lake Washington and Lake Tahoe – and using a variety of statistical techniques to extract important long term trends. I have every confidence she can do this for the Sacramento-San Joaquin delta as well. With the critical importance of this system to Califronia's well being, it is imperative that all that can be extracted from the past data collection efforts be done. Ecological systems are inherently variable, and long term data sets are crucial.

Although many of the current questions are related to fish species, looking at the food web, specifically the phytoplankton and zooplankton dynamics, is the obvious place to search for a better understanding. I totally support the goals, objectives and methods as desribed in the proposal.

Sincerely,

S. Geoffrey Schladow, Ph.D
Director, Tahoe Environmental Research Center
Professor of Water Resources and Environmental Engineering

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Professional Preparation

University of Western Australia	Civil Engineering	B.S.	1974
University of California, Berkeley	Hydraulic Engineering	M.E.	1980
University of Western Australia	Civil Engineering	Ph.D.	1986

Appointments

2004 – present	Founding Director, Tahoe Environmental Research Center
1993 – present	Asst., Assoc., Full Professor, Dept of Civil and Env. Engineering, University of California, Davis
1989 – 1993	Senior Research Fellow, Center for Water Research, University of Western Australia
1986 – 1989	Research Associate, Department of Civil and Environmental Engineering, Stanford University

Selected Publications

Florsheim, J. L.; Mount, J. F.; Hammersmark, C.; Fleenor, Wm. E.; and Schladow, S. G. (submitted) Geomorphic Influence on Flood Hazards in a Lowland Fluvial-Tidal Transitional Area, Central Valley, California. ASCE **J. Natural Hazards Research**.

Barad, M. F., Colella, P. and Schladow, S. G. (In press). An adaptive Cartesian grid projection method for environmental flows. **International Journal for Numerical Methods in Fluids**.

Rueda, F. J., Schladow, S. G. and Clark, J. F. 2007. Mechanisms of contaminant transport in a multi-basin lake. In press, **Ecological Applications**.

Swift, T. J., Perez-Losada, J., Schladow, S. G., Reuter, J. E., Jassby, A. D. and Goldman, C. G. (2006). A mechanistic clarity model of lake waters: Linking suspended matter characteristics to clarity. **Aquatic Sciences** 68, 1-15.

Palmarsson, S. O. and Schladow, S. G. (2006). Boundary flow on a lake slope during Ekman layer arrest. **J. Geophys. Res**., 111, C04006, doi:10.1029/2004JC002827.

Coats, R., Perez-Losada, J., Schladow, S. G., Richards, R.C. and Goldman, C. R. (2006). The Warming of Lake Tahoe. **Climatic Change** 76:121-148.

Hammersmark, C. T., Fleenor, W. E. and Schladow, S. G. (2005). Simulation of Flood Benefit and Habitat Extent for a Tidal Freshwater Marsh Restoration. **Ecological Engineering**, 25(2), 137-152.

Cheong, T. S., Schladow, S. G. and Seo, I. W. (2005). Design and placement of levee breaches to maximize the suspended sediment trapping in rivers. **Proceedings XXXI IAHR Congress**, Seoul, Korea.

Steissberg, T. E., Hook, S. J. and Schladow, S. G. (2005). Characterizing Partial Upwellings and Surface Circulation at Lake Tahoe, California-Nevada, USA with thermal infrared images. **Remote Sensing of the Environment,** 99, 2-15.

Steissberg, T. E., Hook S. J. and Schladow, S. G. (2005). Measuring surface currents in lakes with high spatial resolution thermal infrared imagery. **Geophysical Research Letters**, Vol.32, L11402, doi:10.1029/2005GL022912

Heald, P. C., Schladow, S. G., Reuter, J. E. and Allen, B (2005). Modeling MTBE and BTEX in Lakes and Reservoirs Used for Recreational Boating. Environmental Science and Technology, 39 (4), 1111-1118.

Rueda, F.J., Schladow, S.G. Monismith, S.G. and Stacey, M.T. (2004) On the effects of topography on wind and the generation of currents in a large multi-basin lake. **Hydrobiologia** 532, 139-151.

Ganju, N.K., Schoellhamer, D.H., Warner, J.C., Barad, M.F., and Schladow, S.G. (2004). Tidal oscillation of sediment between a river and a bay: a conceptual model. **Estuarine, Coastal, and Shelf Scienc**e Vol 60/1 pp 81-90.

Schladow, S. G. Palmarsson, S. O., Steissberg, T. E., Hook, S. J. and Prata, F. (2004) An extraordinary upwelling in a deep, thermally stratified lake. **Geophysical Research Letters**, Vol. 31, L15054.

Warner, J. C., Schoellhamer, D. H. and Schladow, S. G. (2003). Tidal truncation and barotropic convergence in a channel network tidally driven from opposing entrances. **Estuarine, Coastal, and Shelf Science** Vol 56, Issue 3-4, pp 629-639.

Rueda, F.J. and Schladow, S.G. (2003) The internal dynamics of a large polymictic lake. Part II: three-dimensional numerical simulations. ASCE **J. Hydraulic Engineering**, 129(2), 92-101.

Rueda, F.J., Schladow, S.G. and Palmarsson, S.O. (2003). Basin-scale internal wave dynamics during a winter cooling period in a large lake. **J. Geophysical Research** 108 (C3), 3097.

COLLABORATORS AND CO-EDITORS (last 48 months)

Brant Allen, UC Davis; Dr Michael Barad, Stanford University; Dr David Barnes, UC Davis; Dr Nicole Beck, 2nd Nature; Dr Fabian Bombardelli, UC Davis; Dr Jon Burau, USGS; Dr Tom Cahill, UC Davis; Dr Sudeep Chandra, UNR; Dr E. Chung, RMA; Dr Jordan Clark, UC Santa Barbara; Dr Robert Coats, Hydroikis;Dr Phil Colella, Lawrence Berkeley Labs; Dr Solomon Dobrowski, University of Montana; Dr David Finger, EAWAG; Dr W. Fleenor, UC Davis; Dr Joan Florsheim, UC Davis; Dr D. Fong, Stanford University; Dr Oliver Fringer, Stanford University; Jehan Fugitt, West-Yost; Neil Ganju, USGS; Dr Michael Gertz, UC Davis; Dr Charles Goldman, UC Davis; Dr Peter Green, UC Davis; Dr Bernd Hamann; Chris Hammersmark, UC Davis; Quinn Hart, UC Davis; Scott Heald, West Yost; Dr Jim Hench, Stanford University; Dr Alan Heyvaert, DRI; Dr David Ho, Lamont-Doherty; Dr Chris Holdren, USBR; Dr Simon Hook NASA/JPL; Dr Alan Jassby; Dr Masoud Kayhanian, UC Davis; Dr Graham Kent, Scripps; Dr Oliver Kreylos, UC Davis; Dr Sally MacIntyre, UC Santa Barbara; Dr Stephen Monismith, Stanford University; Dr Jeff Mount, UC Davis; Dr Jim Oris, Miami University; Dr Svein Palmarsson, Vatnaskil; Dr Adina Paytan, Stanford University; Dr Joaquim Perez-Losada, University of Girona; Dr Bertram Ludaescher, UC Davis; Dr Fred Prata, CSIRO, Australia; John Riverson, TetraTech; Dr Dale Robertson, USGS; Dr John Reuter, UC Davis; Bob Richards, UC Davis; Dr. Francisco Rueda, Univ of Granada; Dr Laurel Saito, UNR; Dr David Schoellhamer, USGS; Dr Ken Smith, UNR; Dr Pete Smith, USGS; Dr Mark Stacey, UC Berkeley; Todd Steissberg, UC Davis; Dr Tom Suchanek, UC Davis; Dr Rick Susfalk, DRI; Dr Ted Swift, DWR; Dr Susan Ustin, UC Davis; Dr Frank Vernon, Scripps; Dr John Warner, USGS; Dr Inge Werner, UC Davis; Dr Susan Williams, Dr Craig Williamson, Miami University; UC Davis; Dr Monika Winder, UC Davis; Dr Wayne Wurtsbaugh, Utah State; Dr Tom Young, UC Davis; Dr Rob Zierenberg, UC Davis;

GRADUATE AND POSTDOCTORAL ADVISORS

Dr Jörg Imberger (thesis advisor), University of Western Australia
Dr Robert L. Street and Dr Jeffrey R. Koseff (postdoctoral advisors), Stanford University

THESIS ADVISOR AND POSTGRADUATE- SCHOLAR SPONSOR

(previous 5 years, of a total of 51 students and 12 postdocs)

PH.D	William Fleenor (UC Davis)	Michael Barad (Postdoc, Stanford)
	Sveinn Palmarsson (Postdoc UC Davis)	Stephen McCord (consultant)
	Francisco Rueda, (Univ Granada)	John Warner (USGS)
	Joaquim Losada (University of Girona)	Eu Gene Chung (consultant)
	Laura DiPalermo (current)	Todd Steissberg (current)
	Kristin Eastman (current)	Stephen Andrews (current)
MS		
	Banu Sunman (consultant)	Raffi Moughamian (government)
	Alexa LaPlante (consultant)	Belen Cardona (PhD candidate)
	Chris Hammersmark (PhD candidate)	Scott Heald (consultant)
	Brian Heiland (government)	Stephen Blake (consultant)
	Sveinn Palmarsson (consultant)	David Jassby (PhD candidate)
	Jehan Fugitt (consultant)	Alex Rabidoux (government)
	Simone Sebalo (current)	Airey Krich-Brinton (consultant)
	Stephen Andrews (PhD candidate)	Lee Guethle (consultant)
	Nathan Bowersox (current)	Matt Zelin (current)
	Laura DiPalermo (PhD candidate)	
PostDoc		
	Dr Joaquim Losada, University of Girona, Spain	Dr Ted Swift, government
	Dr Minhee Lee, Pukyong U., Korea	Dr Francisco Rueda, U. Granada, Spain
	Dr T-S Cheong, Seoul University	Dr William Fleenor, CEE, UC Davis
	Dr Sveinn Palmarsson, Consultant	Dr Goloka Sahoo, current
	Dr Monika Winder, current	Dr Solomon Dobrowski, U. Montana

ETH

DIE EIDGENÖSSISCHE TECHNISCHE HOCHSCHULE ZÜRICH

verleiht durch diese Urkunde auf Antrag des Departementes Umweltnaturwissenschaften

Frau

MONIKA WINDER

Mag.rer.nat. Universität Innsbruck

geboren am 17. Dezember 1970, aus Österreich

aufgrund ihrer Promotionsarbeit

ZOOPLANKTON ECOLOGY IN HIGH-MOUNTAIN LAKES

(Referent: J. V. Ward)

und der mündlichen Prüfung vom 4. Februar 2002

den Titel

DOKTORIN DER NATURWISSENSCHAFTEN

Zürich, den 28. Mai 2002

Im Namen der Eidgenössischen Technischen Hochschule Zürich

DER REKTOR	DER VORSTEHER DES DEPARTEMENTES UMWELTNATURWISSENSCHAFTEN
K. Osterwalder	*P. Edwards*

ETH

Swiss Federal Institute of Technology Zurich

awards through this certificate in order of the Department of Natural Sciences

Ms.
MONIKA WINDER
Mag.rer.Nat. University Innsbruck
born on December 17, 1970 in Austria

due to her dissertation thesis entitles

ZOOPLANKTON ECOLOGY IN HIGH-MOUNTAIN LAKES
(Referee: J.V. Ward)

and the oral exam on February 4, 2002

the title **DOCTOR OF NATURAL SCIENCES**

Zurich, Mai 28, 2002

In behalf of the Federal Institute of Technology Zurich

THE DEAN	THE HEAD OF THE DEPARTMENT OF NATURAL SCIENCES
signature	*signature*
K. Osterwalder	*P. Edwards*

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eawag
aquatic research

CALFED Science Fellows Program

Dübendorf May 30, 2008

Reference letter for Monika Winder

To how it may concern,

It is with great pleasure that I write this letter for my former Ph. D. student Monika Winder. I think she is an outstanding scientist who is well qualified for the CALFED fellowship award.

Monika entered my lab as a Ph. D. student in the beginning of 1998. Her task was to study the aquatic food web of an alpine lake in the Swiss Alps. Especially she had to study the interactions between zooplankton and fish, mediated through chemical signals (kairomones). Her project was part of an EU project "SNIFFS" that investigated these interactions on a broader scale. She worked together with Sandra Lass who started at the same time.

I chose Monika for this position because she had experience with zooplankton analysis of an Austrian alpine lake; furthermore she had already some experience abroad. In the four years Monika has worked in my lab I have never regretted hiring her. Monika is a very intelligent, extremely motivated, friendly, very social, hard-working woman. Her publications show that Monika is a good and productive writer. She knows how to organize and plan her work, how to design experiments to test questions which arose from her field data, and how to handle those questions in a paper.

Monika defended her doctoral thesis successfully on 4 February 2002. Among our department head, Prof. Ward, and me, Prof. Lampert was part of her committee. This because Monika did part of her experimental work at the Max Planck Institute for Limnology in Plön, there she did an experiment in the so-called Plankton Towers. She handled this experiment almost alone; it showed again how hard she works, when necessary to answer a research question. For this stay in Germany she got a grant from the German Academic Exchange Service. Here at EAWAG Monika build up the whole "field work side" of my lab, which made it possible also for others to sample efficient in alpine lakes. Additionally, Monika developed carbon analysis on individual daphnids, and did several in-situ experiments. One was a large enclosure experiment, the other a life history experiment on the border of the alpine lake to test the water of different depths.

Her collaborative skills resulted in a paper together with Michael Monaghan in which Alpine lakes, which were sampled hundred years ago, were re-sampled and analyzed for their species and genetic diversity. This paper was recently published in Arctic Antarctic and Alpine Research. Another example is her interest in modeling aspects of vertical migration of

Daphnia. This resulted in a paper together with Wolf Mooij from the Netherlands that was recently published in Ecology.

In addition to her excellent research skills, Monika also is a good teacher and has various teaching experience at high school and university level. During three semesters, she taught undergraduate and graduate lab courses and supervised diploma (similar to senior thesis) students. Monika took every opportunity to work with students and teach classes and with her enthusiasm was able to motivate many students. I addition, Monika has great communication and leadership skills for teaching and working with students.

Monika Winder is a many-sided aquatic ecologist with a large potential. She did a post-doc at the University of Washington in the group of Prof. Daniel Schindler. For this Project she got a fellowship from the Swiss National Science Foundation (for one year) and from the Austrian Science Foundation (for 18 months) and will be a guest researcher at the School of Aquatic and Fishery Sciences for another year. At the University of Washington Monika developed substantial quantitative skills useful in ecology, which resulted in excellent papers.

Monika Winder's research broadened the last years from Plankton Ecology to Ecosystem research. She collected skills to analyze large datasets with the goals to investigate the effects from global change on Lake Ecosystems. The first results of these projects are just published (Winder, M. and Schindler, D. E. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. - Ecology 85: 2100-2106. and Winder, M. and Schindler, D. E. 2004. Climatic effects on the phenology of lake processes. - Global Change Biology 10: 1-13).

Currently, Monika is involved in the Tahoe Environmental Research Centre at UC Davis were she investigates community responses to external variations on ecosystem dynamics. Given how I got to know Monika in my lab and how she developed further at the University of Washington and California I think Monika would be an ideal candidate for the position you offer because of her excellent skills both in research and teaching. She now reached a point in here career that she is able to handle more complex projects and take on more responsibilities. I am sure Monika would be a perfect candidate for your program and is well qualified to complete the analysis proposed. Therefore I highly recommend Monika Winder for this award.

Sincerely,

Piet Spaak

Group leader, Evolutionary Ecologist

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF ENVIRONMENTAL SCIENCE AND POLICY

ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8576

June 3, 2008

It is my pleasure to write this very strong letter in support of Dr. Monika Winder's application for a 2008 CALFED Science Program fellowship as a post-doctoral researcher. I have worked with Dr. Winder on a number of projects since she first joined our research team in 2005. Examples include: analysis of a 40-year data record from Lake Tahoe on clarity, nutrients and phytoplankton/zooplankton dynamics; food web dynamics in both Lake Tahoe and Castle Lake; biological consequences of climate change in lakes; and pico-plankton identification and population characteristics. These, and other previous investigations she has conducted make her an ideal candidate to study long-term trends and trophic linkages within the San Francisco Estuary plankton community. As she states in her proposal, the detailed responses of zooplankton and their interactions with primary producers and environmental variables have yet to be analyzed using the historical dataset.

Dr. Winder is marvelous at combining the statistical analysis of long-term datasets with a very practical understanding of plankton ecology. Her experience as an experimental limnologist allows her to more deeply understand the physical, chemical and biological mechanisms that control ecosystem response. Her first post-doctoral study at the University of Washington looked at the long-term dynamics of phytoplankton and zooplankton in Lake Washington (since the 1960s) and has been very well received by the scientific community. Her current research using decadal-scale datasets to investigate the impacts of global warming on lake biota and trophic interactions has also been widely recognized. Dr. Winder was invited to be a keynote speaker at the upcoming AGU Chapman Conference on Lakes and Reservoirs as Sentinels, Integrators, and Regulators of Climate Change that will appear as a special issue of Limnology & Oceanography.

Dr. Winder brings considerable scientific talent to addressing an important question regarding the function and management of the Sacramento-San Joaquin Delta and San Francisco Bay. She has been working in close contact with Drs. Alan Jassby, James Cloern and Wim Kimmerer and her proposed work will dovetail nicely into their previous and current efforts. Working with these well-established San Francisco Estuary scientists will provide excellent training as Monika expands her expertise into the discipline of aquatic modeling.

Dr. Winder has the core characteristics needed for a successful research scientist– scholarship, innovative ideas, team-work and desire to improve her skills, energy, dedication to research, reliability, and a desire to participate in public outreach. Monika is without a doubt one of the brightest, engaged and most energetic post-doctoral researchers who has worked with us in my 30 years at UC Davis. She is intellectually very curious and knows what it takes to quickly focus in on asking the right questions and developing the most appropriate design. All her projects include a balanced combination of field sampling, laboratory experiments, and advanced statistical modeling. Her CV shows that she has been able to successfully submit research papers in each the major periods of her academic career. This attests to her ability to rapidly develop a first-class research program.

I believe that her application and research topic is a perfect fit that will benefit both CALFED and Monika. The work she has put into her proposal is a clear indication that she has the ability to identify knowledge gaps. She certainly has the ability to conduct this project and produce first-class scientific papers.

I hoe you will strongly consider her application and please feel free to contact me should you require an additional information,

Regards

John E. Reuter

John E. Reuter, Research Faculty (Full)
Associate Director, Tahoe Environmental Research Center
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530-304-1473

UNIVERSITY OF CALIFORNIA, DAVIS

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DEPARTMENT OF ENVIRONMENTAL SCIENCE AND POLICY

ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8576

June 5, 2007

This letter is written in enthusiastic support of Monika Winders application for a Calfed Fellowship to study the plankton of the San Francisco Estuary utilizing long term trends and trophic linkages. She is joined in this venture by a very talented group of scientific associates. I have read the questions posed and the objectives of this study and find them to be very compelling. Monika is a young top-notch phytoplankton/zooplankton ecologist/limnologist from Austria via her doctoral studies in Switzerland. Following a productive postdoctoral with Professor Daniel Schindler at the University of Washington, Monika joined our Tahoe Environmental Research Center and has put in an outstanding performance. She is bright, articulate and adapted quickly to the problems of primary and secondary productivity at the lake and has published and presented her research widely. She is currently being considered for a regular research position here at UC Davis, which is strong evidence of her talent when one considers that University funds are being cut and people are being discontinued for lack of hiring and support funds.

For many years the outstanding work of scientists like Jassby and Cloern have documented the declining fertility of the Bay-Delta System that has received considerable publicity in the local press, particularly in relation to the decline of the Delta Smelt population as well as of the predatory sport fishes higher in the food chain. The decline in the striped bass population as well as the declining salmon runs is of great concern to fishermen and conservationists alike. Long term data is particularly essential for understanding the population trends in our lakes, streams and the ocean. The fact that a data set exists on the Delta makes this study particularly compelling. Further, the team includes one of the very best long term aquatic data analysts in the country in the form of Dr. Jassby, who is a member of the team. Monika has already demonstrated her skill in this area with Lake Tahoe data and the group assembled can clearly be identified as an "A team" capable of completing this project at the highest level of scientific competence. The study is certain to contribute significantly to our understanding of the food chain dynamics at what is likely a tipping point in the Bay Delta ecology. I strongly support this application and feel it has the highest possible likelihood of success.

Sincerely,

Charles R. Goldman
Distinguished Professor of Limnology
Laureate, Albert Einstein World Award of Science

June 3, 2008

Dr. Monika Winder
Tahoe Environmental Research Center
Center for Watershed Sciences
University of California, Davis CA 95616-8803

Dear Monika,

I just read with great interest your proposal for a Calfed Fellowship to mine the IEP phytoplankton-zooplankton data sets using innovative approaches that have not been applied previously. The objectives of your proposal are highly relevant to the challenge of understanding the causes of pelagic organism declines in the Delta. This is one of the most thoughtful, well-organized proposals I have read in a number of years, and I enthusiastically accept your invitation to serve as community mentor.

Your proposal addresses relevant, first order ecological questions that can be answered with the exceptional data sets documenting changes in phytoplankton and zooplankton communities and biomass across the mosaic of Delta habitats. I'm especially impressed by your plan to quantify spatial and temporal patterns, explore linkages between phytoplankton and zooplankton, and applications of tools such as Multivariate Autoregressive models that have not been exploited to tackle the recalcitrant problem of why zooplankton stocks have collapsed. I'm also very enthusiastic about your approach that focuses on changes in species composition, rather than just biomass, which recognizes the particular importance of changing quality and accessibility of food resources for consumers.

You lay out an exceptionally ambitious plan. However, given your expertise in plankton ecology and the tools you bring to this effort, I am fully certain that your research will significantly advance knowledge of zooplankton ecology in the Delta. I wish you great success and look forward to an opportunity to collaborate with and learn from you in the next few years.

Sincerely,

James E. Cloern
Senior Scientist, USGS, Menlo Park, CA

Anke Mueller-Solger, Ph.D.
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California Department of Water Resources, Division of Environmental Services
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05-04-2008

Support letter for 2008 CALFED Science Fellows Proposal by **Dr. Monika Winder**

To Whom it May Concern:

I am writing to offer my enthusiastic support for a proposal to the CALFED Science Fellows Program by Dr. Monika Winder and to confirm my willingness to serve as a "State agency mentor" for this project.

I am a Staff Environmental Scientist with the California Department of Water Resources and was previously a research scientist at UC Davis. In these capacities, I have been and continue to be intensely involved with a number of research projects funded by the CALFED program as well as with monitoring and research programs conducted in the upper San Francisco Estuary (SFE) by the Bay-Delta Interagency Ecological Program (IEP). I am thoroughly familiar with all IEP monitoring programs and have led the 2001-2002 scientific and management review of the IEP Environmental Monitoring Program (EMP) which collects the data Dr. Winder proposes to analyze. I have also led various planning aspects of CALFED Science Conferences, including serving as Conference Co-Chair for the 2006 and 2008 conferences, and I have participated in many CALFED and IEP workshops. I am also the current chair of the IEP Pelagic Organism Declines (POD) Management Team.

Results of studies coordinated by the POD team point to food limitation and changes in trophic structure and species composition as possible mechanisms leading to the recent precipitous declines of several important fish species in the SFE. Of particular concern are low primary and secondary productivity levels in the Delta and Suisun Bay, especially by taxa recognized as "good food." While phytoplankton trends, and the mechanisms behind these trends, have recently been explored in detail, there have been no comparable analyses for zooplankton. This is in spite of the availability of a very rich and well-documented long-term zooplankton data set and frequent calls for more comprehensive and in-depth analyses of IEP data. Perhaps even more importantly, there have been no attempts at a detailed **integrated** analysis of the available phytoplankton and zooplankton data. Such an analysis is a fundamental contribution to more comprehensive food web modeling, including the POD "systems ecology" modeling currently under way at the National Center for Ecological Analysis and Synthesis in Santa Barbara. This type of modeling is essential for understanding the current ecological state of the estuary, including the mechanisms behind the POD, as well as for predicting the effects of future intentional and unintentional changes that are currently the subject of intense debate by several high-profile Delta planning and management efforts. Ultimately, the work proposed by Dr. Winder may lead to more scientifically sound environmental management strategies aimed at improving the health and resilience of the SFE ecosystem, including its currently threatened and endangered fish species.

Dr. Winder proposes to utilize a number of sophisticated statistical analysis and modeling techniques to address five important and clearly laid out questions about phytoplankton and zooplankton patterns, trends, and interactions in the upper SFE. Dr. Winder has already employed some of these methods in her previous, published work on phytoplankton dynamics and will likely quickly become an expert in the methods she is currently less familiar with, especially since her research and community mentors for this project are all recognized experts in statistical ecology. These mentors and I will also be able to assure good connectivity between Dr. Winder and others working on food web issues in the SFE, including IEP POD, NCEAS, and CALFED investigators, and the SFE monitoring community. I believe that her proposed work will be an excellent complement to ongoing research and monitoring work. Based on her previous research experience, Dr. Winder is clearly highly qualified to conduct this challenging project. She has not worked in the SFE before, but appears very willing and able to quickly learn about this complex system and join its scientific community, bringing a fresh mind and a varied scientific background to this sometimes quite insular community. I am particularly excited that she is willing to take on challenging analyses of the IEP monitoring data sets. Not many researchers have been willing and able to successfully do this in the past, and almost all reviews of the IEP, including a recent review by the CALFED Independent Science Board concluded that there is an urgent need for much more analysis, synthesis, and publication of IEP data. Dr. Winder's project would clearly be a very important step toward achieving this goal.

Dr. Winder's proposed project is of great analytical difficulty and utilizes appropriate techniques and a substantial level of advanced expertise. I believe that it is thus suitable for an academic postdoctoral project under the guidance of experienced research and community mentors. I would be honored to serve as a State Agency mentor for this project and assure close connectedness to SFE issues, State agencies and resources, and the IEP.

Sincerely, Anke Mueller-Solger, CA DWR, Sacramento